Next Generation Science Standards (NGSS) Cluster/Item Specifications

Specifications for High School

Introduction

This document presents *cluster specifications* for use with the Next Generation Science Standards (NGSS). These standards are based on the Framework for K-12 Science Education. The present document is not intended to replace the standards, but rather to present guidelines for the development of items and item clusters used to measure those standards.

The remainder of this section provides a very brief introduction to the standards and the framework, an overview of the design and intent of the item clusters, and a description of the cluster specifications that follow. The bulk of the document is composed of cluster specifications, organized by grade and standard.

Background on the framework and standards

The Framework for K-12 Science Education are organized around three core dimensions of scientific understanding. The standards are derived from these same dimensions:

- Disciplinary Core Ideas: The fundamental ideas that are necessary for understanding a given science discipline. The core ideas all have broad importance within or across science or engineering disciplines, provide a key tool for understanding or investigating complex ideas and solving problems, relate to societal or personal concerns, and can be taught over multiple grade levels at progressive levels of depth and complexity.
- Science and Engineering Practices: The practices are what students DO to make sense of phenomena. They are both a set of skills and a set of knowledge to be internalized. The SEPs reflect the major practices that scientists and engineers use to investigate the world and design and build systems.
- Cross-Cutting Concepts: These are concepts that hold true across the natural and engineered world. Students can use them to make connections across seemingly disparate disciplines or situations, connect new learning to prior experiences, and more deeply engage with material across the other dimensions. The NGSS requires that students explicitly use their understanding of the CCCs to make sense of phenomena or solve problems.
- There is substantial overlap between and among the three dimensions. For example, the cross-cutting concepts are echoed in many of the disciplinary core ideas. The core ideas are often closely intertwined with the practices. This overlap reflects the nature of science itself. For example, we often come to understand and communicate causal relationships by employing models to make sense of observations. Even within a dimension, overlap exists. Quantifying characteristics of phenomena is important in developing an understanding of them, so employing computational and mathematical thinking in the construction and use of models is a very common scientific practice, and one of the cross-cutting concepts suggests that scientists often infer causality by observing patterns. In short, the dimensions are not orthogonal.

The framework envisions effective science education as occurring at the intersection of these interwoven dimensions: students learn science by doing science—applying the practices through the lens of the cross-cutting concepts to investigate phenomena that relate to the content of the disciplinary core ideas.

Item clusters

Each item cluster is designed to engage the examinee in a grade-appropriate, meaningful scientific activity aligned to a specific standard.

Each cluster begins with a phenomenon, an observable fact or design problem that engages student interest and can be explained, modeled, investigated, or designed using the knowledge and skill described by the standard in question.

What it means to be observable varies across practices. For example, a phenomenon for a performance expectation exercising the a*nalyze data* practice may be observable through regularities in a data set, while standards related to the *development and use of models* might be something that can be watched, seen, felt, smelled, or heard.

What it means to be observable also varies across grade levels. For example, elementary-level phenomena are very concrete and directly observable. At the high school level, an observation of the natural world may be more abstract--for example, “observing” changes in the chemical composition of cells through the observation of macroscopic results of those changes on organism physiology, or through the measurement of system- or organ-level indications.

Content limits refine the intent of the performance expectations and provide limits on what may be asked of items in the cluster to structure the student activity. The content limits also reflect the disciplinary core ideas learning progressions that are present in the K-12 Framework for Science Education.

The task or goal should be explicitly stated in the stimulus or the first item in the cluster: statements such as “In the questions that follow, you will develop a model that will allow you to identify moons of Jupiter,” or “In the questions below, you will complete a model to describe the processes that lead to the steam coming out of the teapot.”

Whereas item clusters have been described elsewhere as “scaffolded,” they are better described as providing structure to the task. For example, some clusters begin with students summarizing data to discover patterns that may have explanatory value. Depending on the grade level and nature of the standard, items may provide complete table shells or labeled graphs to be drawn, or may require the student to choose what to tabulate or graph. Subsequent items may ask the student to note patterns in the tabulated or graphed data and draw on domain content knowledge to posit explanations for the patterns.

These guidelines for clusters do not appear separately in the specifications. Rather, they apply to all clusters.

Structure of the cluster specifications

The item cluster specifications are designed to guide the work of item writers and the review of item clusters by stakeholders.

Each item cluster has the following elements:

- The text of the performance expectations, including the practice, core idea, and cross-cutting concept.
- Content limits, which refine the intent of the performance expectations and provide limits of what may be asked of examinees. For example, they may identify the specific formulae that students are expected to know or not know.
- Vocabulary, which identifies the relevant technical words that students are expected to know, and related words that they are explicitly not expected to know. Of course, the latter category should not be considered exhaustive, since the boundaries of relevance are ambiguous, and the list is limited by the imagination of the writers.
- Sample phenomena, which provide some examples of the sort of phenomena that would support effective item clusters related to the standard in question. In general, these should be guideposts, and item writers should seek comparable phenomena, rather than drawing on those within the documents. Novelty is valued when applying scientific practices.
- Task demands comprise the heart of the specifications. These statements identify the types of items and activities that item writers should use, and each item written should be clearly linked to one or more of the demands. The verbs in the demands (e.g., *select, identify, illustrate, describe*) provide guidance on the types of interactions that item writers might employ to elicit the student response. We avoid explicitly identifying interaction types or item formats to accommodate future innovations and to avoid discouraging imaginative work by the item writers.
- For each cluster we present, the printed documentation includes the cluster, the task demands represented by each item, and its linkage to the practice and cross-cutting concept identified in the performance expectation.

Item cluster specifications follow, organized by domain and standard.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS1-1
Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Use a model to predict the relationships between systems or between components of a system.</td><td>PS1.A: Structure and Properties of Matter
• Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
• The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.</td><td>Patterns
• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.

Content Limits
• Assessment is limited to main group elements.
• Assessment does not include quantitative understanding of ionization energy beyond relative trends.
• <u>Students do not need to know:</u> Properties of individual elements, names of groups, anomalous electron configurations (Chromium and Copper)</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Proton, electron, neutron, valence shell, filled shell, ion, cation, anion, metal, nonmetal, metalloid, group, period, family, pure substance, atomic number, atomic symbol, atomic weight, ionic bond, covalent bond, s, p, d, f orbitals, electron configuration, core electrons, nucleus, single, double, triple bond(s), molar mass, atomic radius, electronegativity,</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Oxidation state, diatomic, polyatomic ions, empirical formulas, molecular formulas, quantum, photon, Heisenberg Uncertainty Principle, Hund’s Rule, Pauli Exclusion Principle</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS1-1:
• Potassium chloride (KCl) tastes similar to table salt (sodium chloride (NaCl)).
• Balloons are filled with helium gas instead of hydrogen gas.
• Scientists work with silicate substrates in chambers filled with Argon instead of air.
• Diamond, graphene, and fullerene are different molecules/materials that are only made of carbon.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Select or identify from a collection of periodic table components (periods, groups, etc.), including distractors, the components needed to model the phenomenon.</td></tr>
<tr><td colspan="4">2. Make predictions about the properties of elements based on the number of valence electrons. Predictions can be made by completing illustrations or selecting from lists with distractors.</td></tr>
<tr><td colspan="4">3. Identify missing components, relationships, or other limitations of the model. (Hydrogen similar to Alkali metals, one valence electron, and Halogens, missing only one valence electron).</td></tr>
</table>

4. Describe, select, or identify the relationships among components of the periodic table that describe the properties of valence electrons, or explains the properties of elements.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS1-2
Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.</td></tr>
<tr><td>Dimensions</td><td>Constructing explanations and designing solutions
• Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>PS1.A: Structure and Properties of Matter
• The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

PS1.B: Chemical Reactions
• The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.</td><td>Patterns
• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.

Content Limits
• Assessment is limited to chemical reactions involving main group elements and combustion reactions.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Reversible, atomic weight, chemical bond, electron sharing, ion, outer electron state, energy level, electron transfer, concentration, equilibrium, endothermic, exothermic, stable, combustion, yield(s), flammability, octet</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Molecular orbital diagram, multiplicity, antibonding orbitals, rearrangement, by-product, oxidation-reduction reaction, decomposition, single replacement reaction, double replacement reaction, synthesis reaction, precipitate</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS1-2:
• A coal oven without proper ventilation produces billows of dark smoke.
• Two metals are placed in water. One bubbles and fizzes, while the other gives off a yellow flame and white smoke.
• Carlsbad Caverns is a large cave in New Mexico. Inside, large pointy structures appear to be growing from the ceiling.
• A shiny metallic solid is combined with a green gas, resulting in a white crystalline solid.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Use relationships identified in the data to predict properties of other chemical compounds, elements, and/or mixtures.</td></tr>
</table>

2.	Identify patterns or evidence in the data that supports inferences about the properties of other chemical compounds/elements/mixtures.
3.	Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations.
4.	Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
5.	Use an explanation to predict the properties of other chemical compounds/elements/mixtures given a change in reagents or conditions.
6.	Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations relating to the periodic table. This may include sorting out distractors.
7.	Select, articulate, or construct an explanation about a chemical reaction. This may include identifying/selecting the products of the reaction as part of an explanation.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS1-3
Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.</td><td>PS1.A Structure and Properties of Matter
• The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.</td><td>Patterns
• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on understanding the strength of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole).
• Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite).
• Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.

Content Limits
• Assessment does not include Raoult’s law, nor calculations of vapor pressure.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Nucleus, proton, electron, neutron, electron cloud, intramolecular force, covalent bond, ionic bond, intermolecular force, electrostatic force, electronegativity, electron distribution, polarity, temporary polarity, permanent polarity, polarize, surface area, atomic radius, atomic weight, atomic mass, solute, solvent, dissolve.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Dipole, induced dipole, dipole moment, delta, Coulomb’s law, dipole-dipole, London forces, Van der Waals forces, ion-dipole, hydrogen bonding, pi-electron cloud, pi stacking, colligative properties, electron shielding.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS1-3:
• Two neighbors apply different salt treatments to their driveways the night before a freeze is predicted. The next morning, no ice formed on one of their driveways. However, the other driveway was covered with a thin layer of ice.
• A chef makes salad dressing by completely mixing oil, water, and vinegar in a large container. Afterwards, he pours the mixed dressing from the large container into individual containers and places one container on each of the restaurant’s tables before leaving for the night. In the morning, the chef finds a layer of oil floating on top of a liquid layer in each of the containers on the tables.
• After working with painting oils, an artist finds that she must wash her hands with soap and water to remove the oil from her hands, as rinsing with water alone does not remove the oil.
• A glass is completely filled with water. When coins are added to the full glass of water, the surface of the water rises above the rim of the glass without spilling.</td></tr>
<tr><td colspan="4" align="center">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
</table>

Task Demands
1. Identify from a list, including distractors, the materials/tools needed for an investigation of the physical properties/interactions of atomic and/or molecular substances at the bulk scale to gather evidence about the strengths of the electrostatic attractions between the particles of those substances.
2. Identify the outcome data that should be collected in an investigation of the physical properties/interactions of atomic and/or molecular substances at the bulk scale to gather evidence about the strengths of the electrostatic attractions between the particles of those substances.
3. Evaluate the sufficiency and limitations of collected data about the physical properties/interactions of substances at the bulk scale to explain the phenomenon.
4. Make and/or record observations about the physical properties/interactions of substances at the bulk scale that provide evidence to support inferences about the relative strengths of the electrostatic attractions between the particles of those substances.
5. Interpret, summarize, and/or communicate the data from an investigation concerning the physical properties/interactions of substances at the bulk scale.
6. Explain or describe the causal processes that lead to the observed data.
7. Select, describe, or illustrate a prediction concerning the physical properties of or interactions between additional substance(s), and/or the strength of electrostatic attractions between the particles of additional substance(s), made by applying the findings from an investigation.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS1-4
Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>PS1.A: Structure and Properties of Matter
• A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.

PS1.B: Chemical Reactions
• Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.</td><td>Energy and Matter
• Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawing and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.

Content Limits
• Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Transfer, heat energy, atomic arrangement, stored energy, conversion, bond energy, release of energy, endothermic, exothermic</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Recombination of chemical elements, stable, chemical system, chemical reaction rate</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS1-4:
• Scientists gather samples of rock from the ocean floor. One sample looks and feels like ice, but burns and produces a flame when ignited.
• Wet cement is left sitting outside. After one day, the cement becomes hard and stiff.
• A temperature of a sample of tin is lowered from room temperature to 0 °C. The tin changes color from silver to gray, becomes brittle, and starts developing cracks on its surface.
• Baking soda is added to a container of citric acid at room temperature. The resulting solution becomes cold, and returns back to room temperature after 2 minutes.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

1.	Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include models of bonds breaking and forming, heat absorbed or released, or aspects of a chemical reaction.
2.	Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing a release or absorption of energy from a chemical reaction. This does not include labeling an existing diagram.
3.	Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.
4.	Make predictions about the effects of changes in bond energies. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
5.	Describe, select, or identify the relationships among components of a model that describes a release or absorption in energy, or explains why a release or absorption in energy is dependent on total bond energy.

Performance Expectation	**HS-PS1-5** Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.		
Dimensions	**Constructing Explanations and Designing Solutions** • Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.	**PS1.B: Chemical Reactions** • Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
Clarifications and Content Limits	**Clarification Statements** • Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules. **Content Limits** • Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.		
Science Vocabulary Students are Expected to Know	Stored energy, heat energy, atomic arrangement, conversion, bond energy, endothermic, exothermic, concentration, reaction rate, activation energy, catalyst, enzyme, equilibrium		
Science Vocabulary Students are Not Expected to Know	Recombination of chemical elements, stable, chemical system, rate laws, Le Chatelier's principle, rate constant, zero order reactions, first order reactions, stepwise reactions, rate-determining step, steady state, half-life, free radicals, entropy, Gibb's free energy		
Phenomena			
Context/ Phenomena	Some example phenomena for HS-PS1-5: • One bowl of bread dough was set aside to rise in a cool area of a kitchen. Another was set aside to rise near the warm oven. The dough near the oven rose faster than the dough set in the cool area. • A marble stone was exposed to rain water with different acidities on two different spots on the stone. After some time, one spot on the stone was more eroded than the other. • Cookies baked in an oven set to 170°C took longer to bake than cookies baked in an oven set to 220°C. • Inside a fume hood, an adult wearing gloves and goggles carefully added hydrochloric acid to a solution containing sodium thiosulfate ($Na_2S_2O_3$) and a yellow solid appeared in the test tube. Then, dilute hydrochloric acid was added to a second test tube of $Na_2S_2O_3$, and the yellow solid took longer to appear.		
This Performance Expectation and associated Evidence Statements support the following Task Demands.			
Task Demands			
1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.			

2. Express or complete a causal chain explaining how temperature and/or concentration changes can change the rate of a chemical reaction. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.*
3. Identify patterns or evidence in the data that supports inferences about the effects of changing temperature or concentration on the rate at which a chemical reaction occurs.
4. Use an explanation to predict the changes in the rate of other chemical reactions, given a change in reagents or conditions, including temperature and concentration of reactants.
5. Select, articulate, or construct an explanation about a chemical reaction. This may include identifying/selecting the products of the reaction as part of an explanation.*
6. Use evidence to construct an explanation of how changing temperature or concentration of reacting particles on the rate of a reaction.*

*denotes task demands that are approved for use with standalones.

Performance Expectation	**HS-PS1-6** Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.		
Dimensions	**Constructing Explanations and Designing Solutions** • Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**PS1.B: Chemical Reactions** • In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. **ETS1.C: Optimizing the Design Solution** • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. *(secondary)*	**Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable.
Clarifications and Content Limits	**Clarification Statements** • Emphasis is on the application of Le Chatelier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. • Examples of designs could include different ways to increase product formation including adding reactants or removing products **Content Limits** • Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.		
Science Vocabulary Students are Expected to Know	Surface area of reactants, dynamic, thermal energy, heat energy, atomic arrangement, equilibrium, bond energy, endothermic, exothermic, catalyst, chemical bond, mole, element, compound, concentration, Le Chatelier's principle		
Science Vocabulary Students are Not Expected to Know	Recombination of chemical elements, stable, chemical system, chemical reaction rate		
Phenomena			
Context/ Phenomena	Some example phenomena for HS-PS1-6: • Leftover food left on the counter overnight spoils more quickly than food stored in the refrigerator at 1.6˚C. • Several drops of hydrochloric acid were added to an orange mixture of water and potassium dichromate (K_2CrO_7). The mixture turned yellow. • In the 1970s scientists observed that the concentration of ozone (O_3) in the upper atmosphere began decreasing. • A bottle of carbonated soda appears to have fewer bubbles before it is opened than after it is opened.		
This Performance Expectation and associated Evidence Statements support the following Task Demands.			
Task Demands			

1.	Express or complete a causal chain explaining the chemical processes that resulted in a shift in equilibrium. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.
2.	Describe, identify, and/or select evidence supporting the inference of causation that is expressed in a causal chain and/or an explanation of the processes that cause the observed results.
3.	Predict the direction or the relative magnitude of a change in equilibrium of a chemical system, given a change in the amount/concentration of chemical substances in the system, the temperature of the substances in the system, and/or the amount of pressure applied to the substances in a system.
4.	Identify or assemble from a collection, including distractors, of the relevant aspects of the problem that a given design solution, if implemented, will resolve or improve.
5.	Using the given information, select or identify the criteria against which the solution should be judged.
6.	Using given data, propose, illustrate, or assemble a potential solution that would shift equilibrium to favor the products of a chemical reaction.
7.	Using a simulator, test a proposed solution and evaluate the outcomes, potentially including proposing and testing modifications to the solution.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS1-7
Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Use mathematical representations of phenomena to support claims.</td><td>PS1.B Chemical Reactions
• The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.</td><td>Energy and Matter
• The total amount of energy and matter in closed systems is conserved.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale.
• Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.

Content Limits
• Assessment does not include complex chemical reactions.
• <u>Students do not need to know:</u> Properties of individual elements</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">mole, molar ratio, molar mass, limiting reactant, excess reactant, yield(s), theoretical yield, actual yield, concentration, conversion, reversible, ion, cation, anion, metal, nonmetal, metalloid, pure substance, atomic number, atomic symbol, atomic weight, ionic bond, covalent bond</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Dimensional analysis, stoichiometry, (dynamic) equilibrium, La Chatlier's Principle, oxidation state, diatomic, polyatomic ion, empirical formula, by-product, oxidation-reduction reaction, decomposition, single replacement reaction, double replacement reaction, synthesis reaction, combustion reaction, precipitate, solvent, solute, reaction rate, recombination of chemical elements, stable</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS1-7:
• Methane gas flows into a Bunsen burner. When a spark is applied, methane gas reacts with oxygen in the air to produce a blue flame. The flame gets larger as the oxygen valve is turned to allow more oxygen to mix with methane.
• Different masses of baking soda are placed inside three balloons of the same size. Three grams of baking soda is added to the first balloon, four grams is added to the second balloon, and five grams is added to the third balloon. Each balloon is placed on top of a bottle containing 200mL of vinegar, with care that no baking soda is lost from the balloons. When the baking soda inside each balloon drops into the vinegar, the balloons eventually inflate. The balloon containing 4g of baking soda inflates to a larger size than the balloon containing 3g. However, the balloon containing 5g of baking soda inflates to the same size as the balloon containing 4g.
• When colorless solutions of sodium sulfate (Na_2SO_4) and strontium nitrate ($Sr(NO_3)2$) are mixed, a white solid forms. Equal masses of the white solid are recovered when 30.0 mL of 0.10 M Na_2SO_4 solution is added to 70.0 mL of 0.20 M $Sr(NO_3)_2$ solution and when 30.0 mL of 0.20 M Na_2SO4 solution is added to 70.0 ml of 0.20 M $Sr(NO_3)_2$ solution.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

1. Make simple calculations using given data to estimate, calculate, and/or predict the masses of substances involved in a chemical reaction. These calculations may include the optimal ratio of reactants for a chemical reaction, mass of the limiting reactant, the mass of the excess reactant, theoretical yield, and actual yield.
2. Illustrate, graph, describe, and/or identify the proportional relationships between substances involved in a chemical reaction that can be used to calculate or estimate the masses of atoms in the reactants and the products of that chemical reaction.
3. Describe and predict simple chemical reactions in terms of mass, using proportional relationships among the substances involved in a chemical reaction.
4. Compile, from given information, the particular data needed for a particular inference about the amounts of matter within a chemical system. This can include sorting out the relevant data from the given information.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS1-8
Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>PS1.C: Nuclear Processes
• Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.</td><td>Energy and Matter
• In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.

Content Limits
• Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Absorption, transformation, nuclear reaction, nucleus, decay rate, fission, fusion, neutron, nuclear mass, unstable, half-life, radioactive, radiation, alpha particle, alpha decay, beta particle, beta emission, gamma radiation, atomic number, atomic mass, proton, radioactive decay</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Nucleon(s), radioisotopes, positron, positron emission, electron capture, radioactive series, nuclear disintegration series, magic numbers, nuclear transmutations, particle accelerators, transuranium elements, radiometric dating, becquerel (Bq) unit, curie (Ci) unit, Geiger counter, radiotracer, critical mass, supercritical mass, nuclear reactor, ionizing radiation, nonionizing radiation, target nucleus, bombarding particle, nuclear process, nuclear stability, particle emission, rate of nuclear decay, spontaneous nuclear reaction</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS1-8:
• Rocks from the Tuna Creek area of the Grand Canyon were tested and found to contain less lead (Pb) and more uranium (U) than rocks from the Elves Chasm area of the Grand Canyon.
• A brand new nuclear fuel rod containing 3% U-235 was used in a nuclear reactor in New Jersey for 18 months. When it was taken out the reactor, it was found to contain 0.8% U-235, 5.2% fission products, and 1.2% plutonium.
• Scientists in Dubna, Russia, after using a heavy ion accelerator to smash berkelium and detected atoms of elements 115 and 113 along with alpha particles.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Select or identify from a collection of components, including distractors, the components needed to model the changes in nuclear composition and energy released during fission, fusion, and/or radioactive decay.</td></tr>
<tr><td colspan="4">2. Identify missing components, relationships, or other limitations of the model.</td></tr>
<tr><td colspan="4">3. Describe, select, or identify the relationships among components of the nucleus and/or nuclear processes that explains the release or absorption of energy and/or the conservation of protons and neutrons.</td></tr>
</table>

4.	Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing a release or absorption of energy from a nuclear process. This does not include labeling an existing diagram.
5.	Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS2-1
Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.</td><td>PS2.A: Forces and Motion
• Newton’s second law accurately predicts changes in the motion of macroscopic objects.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.

Content Limits
• Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.
• Stating the law or naming the law is not part of this PE.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Velocity, acceleration, net force, friction, air resistance, impulse, vectors, slope, y-intercept</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Jerk, terminal velocity</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">The phenomenon for these PEs are the given data. Phenomena should describe the data set(s) to be given in terms of patterns or relationships to be found in the data, and the columns and rows of a hypothetical table presenting the data, even if the presentation is not tabular. The description of the phenomenon should describe the presentation format of the data (e.g., maps, tables, graphs, etc).

Some example phenomena for HS-PS2-1:
• Force is removed from two vehicles’ accelerator pedals. The vehicles’ positions over time are given.
• A water tank railcar is pulled by a train engine at constant speed and develops a leak allowing water to escape. The position and velocities of the water tank and train over time are given.
• A heavy model rocket rises a shorter distance than a lighter model rocket using the same type of engine. The position of each rocket over time is given.
• A falling skydiver’s velocity increases for several minutes and then reaches a maximum speed. The velocity of the skydiver over time is given.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

1.	Organize and/or arrange (e.g., using illustrations and/or labels), make calculations, or summarize data to highlight trends, patterns, or correlations.
2.	Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends or relationships in the motion of a macroscopic object. This may include sorting out distractors.
3.	Construct, state, or select a claim or propose a design solution based on the relationships identified in the data.
4.	Use relationships identified in the data to predict the motion of and changes in the motion of macroscopic objects.
5.	Identify patterns or evidence in the data that supports inferences about the motion of and changes in the motion of macroscopic objects.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS2-2
Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Use mathematical representations of phenomena to describe explanations</td><td>PS2.A: Forces and Motion
• Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.
• If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.</td><td>Systems and System Models
• When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle
• Students should not be deriving formulas but can be using and manipulating them

Content Limits
• Assessment is limited to systems of no more than two macroscopic bodies moving in one dimension.
• <u>Students do not need to know:</u>
o How to use a derivation to show that momentum is conserved only when there is no net force.
o How to derive formulas regarding conservation of momentum.
o How to resolve vectors and apply the understanding that momentum must be conserved in all directions.
o Newton’s Laws by name</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Friction, transfer, deceleration, frame of reference, net force, acceleration, velocity, internal, external, conversion, closed system, Newton’s Second Law, collision, vector</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Elastic collision, inelastic collision, inertial frame of reference</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS2-2:
• A pool player hits a cue ball towards a stationary 8-ball. The cue ball collides with the 8-ball, causing the 8-ball to move. The 8-ball slows down until it comes to a rest 5 seconds after the collision.
• Two pool balls collide with each other and two soccer balls collide with each other. After the collision, the soccer balls come to a stop quicker than the pool balls.
• A pool player hits a cue ball towards a stationary 8-ball. The cue ball collides with the 8-ball. The velocity of the 8-ball 1 second after the collision is greater than the velocity of the 8-ball 2 seconds after the collision.
• Two hockey pucks collide during an ice hockey practice. A player realizes that the two pucks take a long time to come to rest on the ice. After practice, he makes two street hockey</td></tr>
</table>

	pucks collide on pavement. The pucks come to a stop more quickly than the ones on the ice did.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Make simple calculations using given data to calculate or estimate the total momentum in the system OR the momentum of individual objects within the system.
2. Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate the total momentum in the system OR the momentum of individual objects within the system.
3. Calculate or estimate properties or relationships between momentum and other forces based on data from one or more sources.
4. Identify data or compile from given information, the information needed to support inferences about net force and/or how momentum is conserved within a system. This can include sorting out the relevant data from the given information.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS2-3
Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.</td><td>PS2.A: Forces and Motion
• If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.

ETS1.A: Defining and Delimiting an Engineering Problem
• Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary)

ETS1.C: Optimizing the Design Solution
• Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary)</td><td>Cause and Effect
• Systems can be designed to cause a desired effect.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it.
• Examples of a device could include a football helmet or a parachute.

Content Limits
• Assessment is limited to qualitative evaluations and/or algebraic manipulations</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Exert, acceleration, deceleration, impact, inertia, Newton’s First law, Newton’s Second Law, Newton’s Third Law of Motion, impact, drag, velocity, qualitative, criteria, theoretical model, optimal, deformation, impulse, tradeoff</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Rationale, aesthetics, consideration, representation, aspect, specification, critical, compressibility</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Engineering standards are built around meaningful design problems rather than phenomena. For this performance expectation, the design problem and solutions replace phenomena.

Some example design problems for HS-PS2-3:
• Bikers need to be both protected and have total visibility when riding. Design a helmet that protects the biker from collisions while maintaining awareness for his surroundings.
• Phone screens can be easily broken if dropped on the ground. Design a phone case that protects the phone from collisions while maintaining functionality.
• Design a material that can be implemented on a pool table, athletic field turf (fake grass), or miniature golf green to prevent wear and tear on the playing surface.
• Design an instrument case so that the instrument will still be in good condition even if the case is subject to being dropped or rolled around.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Identify or assemble from a collection, including distractors, the relevant aspects of the problem, that with the given design solutions, if implemented, will resolve/improve the device by minimizing impact force.	
2. Using the given information, select or identify the criteria against which the device or solution should be judged.	
3. Using given data, propose/illustrate/assemble a potential device (prototype) or solution in order to minimize impact forces.	
4. Using given information, select or identify constraints that the device or solution must meet.	
5. Using a simulator, test a proposed prototype and evaluate the outcomes, potentially including proposing and testing modifications to the prototype.	

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS2-4
Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Use mathematical representations of phenomena to describe explanations.</td><td>PS2.B: Types of Interactions
• Newton’s law of universal gravitation and Coulomb’s law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
• Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.</td><td>Patterns
• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.

Content Limits
• Assessment is limited to systems with two objects.
• Mathematical models can involve a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">conductor, induced electric current, electric field, electromotive force, electromagnetic field, electromagnet, frequency, induction, insulator, magnetic field, magnetic field lines, polarity, resistance, voltage, ampere, volts, right-hand rule, tesla, vectors</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">electric potential, electromotive force, permeating, quantum property, Laplace force, electrodynamics, magnetic dipole, electrostatic, general relativity, Ampere’s Law, Coulomb force, Lorentz force</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS2-4:
• Paperclips on a table are picked up by a wire when both ends of the wire are attached to a battery.
• When an electric current flows through a coil near a strong magnet, the coil rotates.
• The light bulb in a closed circuit turns on when a magnet moves near the wire in the circuit.
• A wind turbine built with a neodymium magnet produces more electricity than a wind turbine built with a ferrite magnet.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify from a list, including distractors, the materials/tools/steps needed for an investigation to provide evidence that an electric current produces a magnetic field or that a changing magnetic field produces an electric current.</td></tr>
<tr><td colspan="4">2. Identify the outcome data that should be collected in an investigation to provide evidence that an electric current produces a magnetic field or that a changing magnetic field produces an electric current.</td></tr>
</table>

3.	Evaluate the sufficiency and limitations of data collected to explain the phenomenon.
4.	Make and/or record observations about the magnetic field created by an electric current or the electric current created by a changing magnetic field.
5.	Analyze, manipulate, interpret and/or communicate the data from an investigation to provide evidence that an electric current produces a magnetic field or that a changing magnetic field produces an electric current.
6.	Explain or describe the causal processes that lead to the observed data.
7.	Select, describe, or illustrate a prediction made by applying the findings from an investigation about electric currents and magnetic fields.

Performance Expectation	**HS-PS2-5** Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.		
Dimensions	**Planning and Carrying Out Investigations** • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	**PS2.B: Types of Interactions** • Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. **PS3.A: Definitions of Energy** • “Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents. *(secondary)*	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
Clarifications and Content Limits	**Content Limits** • Assessment is limited to designing and conducting investigations with provided materials and tools. • Coulomb Law is provided in the stimulus if student is required to make calculations.		
Science Vocabulary Students are Expected to Know	conductor, electric charge, induced electric current, electromotive force, electromagnetic field, electromagnet, induction, insulator, magnetic field, magnetic field lines, permanent magnet, polarity, resistance, voltage, magnitude, ampere, charged particle, volts, right-hand rule, tesla, vectors,		
Science Vocabulary Students are Not Expected to Know	electric potential, electromotive force, permeating, quantum property, Laplace force, electrodynamics, magnetic dipole, electrostatic, general relativity, Ampere’s Law, Coulomb force, Lorentz force		
Phenomena			
Context/ Phenomena	Some example phenomena for HS-PS2-5: • Paperclips on a table are picked up by a wire when both ends of the wire are attached to a battery. • When an electric current flows through a coil near a strong magnet, the coil rotates. • The light bulb in a closed circuit turns on when a magnet moves near the wire in the circuit. • A wind turbine built with a neodymium magnet produces more electricity than a wind turbine built with a ferrite magnet.		
This Performance Expectation and associated Evidence Statements support the following Task Demands.			
Task Demands			
1. Identify from a list, including distractors, the materials/tools/steps needed for an investigation to provide evidence that an electric current produces a magnetic field or that a changing magnetic field produces an electric current.			
2. Identify the outcome data that should be collected in an investigation to provide evidence that an electric current produces a magnetic field or that a changing magnetic field produces an electric current.			
3. Evaluate the sufficiency and limitations of data collected to explain the phenomenon.			

4.	Make and/or record observations about the magnetic field created by an electric current or the electric current created by a changing magnetic field.
5.	Analyze, manipulate, interpret and/or communicate the data from an investigation to provide evidence that an electric current produces a magnetic field or that a changing magnetic field produces an electric current.
6.	Explain or describe the causal processes that lead to the observed data.
7.	Select, describe, or illustrate a prediction made by applying the findings from an investigation about electric currents and magnetic fields.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS2-6
Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating Information
• Communicate scientific information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).</td><td>PS1.A: Structure and Properties of Matter
• The structure and properties of matter at the bulk scale are determined by electrical forces within and between atoms. (secondary)

PS2.B: Types of Interactions
• Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, ad transformations of matter, as well as the contact forces between material objects.</td><td>Structure and Function
• Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the attractive and repulsive forces that determine the functioning of the material.
• Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.
• Assessment is limited to provided molecular structures of specific designed materials.

Content Limits
• <u>Students do not need to know:</u> specific molecular structures; specific names of synthetic materials such as vinyl, nylon, etc.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Macroscopic, microscopic, electrical conductivity, long chained molecules, contact force, electron sharing, electron transfer, polymers, network material, surface tension, synthetic polymer, monomer, reactivity, intermolecular forces, charge, conductor, electric charge, insulator, permanent magnet, polarity, resistance, charged particle, ionic bond, covalent bond, hydrogen bond, ductile, malleable, friction</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">electric potential, electromotive force, permeating, quantum property, Laplace force, electrodynamics, magnetic dipole, electrostatic, general relativity, Ampere's Law, Coulomb force, Lorentz force, Van der Waals forces, organic molecules</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS2-6:
• Zinc oxide was dissolved in water and the resulting solution was very difficult to stir. Upon the addition of a clear, amber colored liquid, the solution became much thinner and easier to stir.
• Water was spilled on two shirts. One shirt absorbed the water very quickly, leaving a large wet spot. On the other shirt, the water formed tiny spheres and bounced off, leaving the shirt dry.
• A sample of cotton fabric was dyed with two different kinds of dye and then was washed several times to determine how well the dye stayed in the fabric. One dye faded over time, the other did not.</td></tr>
</table>

	• Food cooked in a bronze-colored pot cooked quickly and evenly. Food cooked in a silver-colored pot took longer and was not evenly cooked.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Analyze and interpret scientific evidence from multiple scientific/technical sources including text, diagrams, charts, symbols, mathematical representations that provide evidence that electrostatic forces on the atomic and molecular scale result in contact forces (e.g., friction, normal forces, stickiness) on the macroscopic scale.*
2. Identify relationships or patterns in scientific evidence to describe how electrostatic forces are related to properties of designed materials.
3. Identify and communicate evidence for how the structure and properties of matter and the types of interactions of matter at the atomic scale determine its function.
4. Synthesize an explanation for the function and properties of designed materials that incorporates the scientific evidence from multiple sources.*
5. Evaluate the validity, credibility, accuracy, relevancy and/or possible bias of scientific/technical sources.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS3-1
Create a computational model to calculate the change in energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Create a computational model or simulation of a phenomenon, designed device, process or system</td><td>PS3.A: Definitions of Energy
• Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system’s total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.

PS3.B: Conservation of Energy and Energy Transfer
• Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
• Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
• Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
• The availability of energy limits what can occur in any system.</td><td>Systems and System Models
• Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on explaining the meaning of mathematical expressions used in the model.

Content Limits
• Assessment is limited to:
o Basic algebraic expressions or computations
o Systems of two or three components
o Thermal energy, kinetic energy, and/or the energies in gravitational, magnetic and electric fields.
• <u>Students do not need to know:</u> detailed understanding of circuits or thermodynamics</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Mechanical energy, potential energy, conversion, kinetic energy, conduction, electrical circuit, electrical current, heat radiation, insulate, resistor, Volt, Amp, Ohm’s Law</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Entropy, second law of thermodynamics, thermodynamics, Stirling cycle, Carnot cycle, capacitor, inductance, inductor, Faradays law</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
</table>

Context/ Phenomena	Some example phenomena for HS-PS3-1: • A block is attached to a spring and laid down on a table. The spring is stretched by pulling the block a certain distance. The spring is then released. As the block oscillates back and forth, the amplitude of each successive oscillation gets smaller until the block stops moving. • A light bulb is hooked up to an energy source. When a resistor is added in series to the circuit, the brightness of the light bulb dims. • Two metal pots are placed on a stove top. Pot 1 has a metal handle while Pot 2 has a rubber handle. The stove is turned on and the pots heat up. After 10 minutes, the handle on Pot 1 is much hotter than the handle on Pot 2. • A toy truck is placed at the top of a frictionless ramp. When it travels down the ramp it collides with a stationary toy truck sitting on a horizontal surface (with friction) at the bottom of the ramp. The truck at the bottom of the ramp then begins to move.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Make simple calculations using given data to calculate or estimate the amount of energy in certain components of the system.
2. Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate how energy changes in one component of the system affect the energy changes in another component of the system OR how the flow of energy into and out of the system affects the energy change of each component within the system.
3. Calculate or estimate properties for, or the relationships between, each component of the system based on data from one or more sources.
4. Compile, from given information, the particular data needed for a particular inference about how energy changes in one component of the system affects the energy changes in another component of the system. This can include sorting out the relevant data from the given information.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS3-2
Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system</td><td>PS3.A: Definitions of Energy
• Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system’s total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
• At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light and thermal energy.
• These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields movers across space.</td><td>Energy and Matter
• Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of phenomena at the macroscopic scale could include:
o The conversion of kinetic energy to thermal energy
o The energy stored due to position of an object above the Earth
o The energy stored between two electrically-charged plates.
• Examples of models could include diagrams, drawings, descriptions, and computer simulations

Content Limits
• <u>Students do not need to know:</u>
o Thermodynamics in detail
o Gravitational fields
o Thermonuclear fusion</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Mechanical energy, potential energy, kinetic energy, electric field, magnetic field, molecular energy, heat conduction, circuit, current, heat radiation, work</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Entropy, Second Law of Thermodynamics, thermodynamics, root mean velocity, Boltzmann’s constant, gravitational fields, fusion, fission</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
</table>

<table>
<tr><td>Context/
Phenomena</td><td>Some example phenomena for HS-PS3-2:
• Two electrically charged plates, one with a positive charge and one with a negative charge, are placed a certain distance apart. Electron 1 is placed in the middle of the two plates. It accelerates to the positive plate and hits it with a certain velocity. Electron 2 is then placed closer to the negative plate. This electron gains more speed before reaching the positive plate.
• A gas is placed inside a container and sealed with a piston. The outside of the container is heated up. The piston begins to move upwards.
• A person rubs their hands together. Afterwards their hands feel warm.
• A block is attached to a spring and placed on a horizontal table. When the spring is un-stretched, the spring and block do not move. When the spring is stretched to a certain distance (x), the block oscillates back and forth.</td></tr>
<tr><td colspan="2">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="2">Task Demands</td></tr>
<tr><td colspan="2">1. Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include equations used to calculate energy or objects used to set up the experimental model. The model can be a conceptual model (flow chart).</td></tr>
<tr><td colspan="2">2. Manipulate the components of a model to demonstrate how energy at the macroscopic scale can be accounted for as a combination of energy associated with the workings of particles at the microscopic scale, result in the observation of the phenomenon.</td></tr>
<tr><td colspan="2">3. Make predictions about the effects of changes in the motion or relative position of objects in the model. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.</td></tr>
<tr><td colspan="2">4. Identify missing components, relationships, or other limitations of the model showing how energy at the macroscopic scale is affected by the motion and positioning of particles at the microscopic scale.</td></tr>
<tr><td colspan="2">5. Describe, select, or identify the relationships among components of a model that describes, or explains, how energy is related to the motion and relative position of objects.</td></tr>
</table>

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS3-3
Design, build and refine a device that works within given constraints to convert one form of energy into another form of energy.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Design, evaluate, and/or refine a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations.</td><td>PS3.A: Definitions of Energy
• At the macroscopic scale, energy manifests itself in multiple ways such as in motion, sound, light and thermal energy.

PS3.D: Energy in Chemical Processes
• Although energy cannot be destroyed, it can be converted to less useful forms – For example, to thermal energy in the surrounding environment.

ETS1.A: Defining and Delimiting an Engineering Problem
• Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary)</td><td>Energy and Matter
• Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on both qualitative and quantitative evaluations of devices.
• Examples of constraints could include use of renewable energy forms and efficiency.
• Examples of devices could include, but are not limited to:
    ○ Rube Goldberg devices
    ○ Wind Turbines
    ○ Solar cells
    ○ Solar ovens
    ○ Generators

Content Limits
• Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Electric current, electrical energy, electromagnet, magnetic field, electric field, mechanical energy, renewable energy, generator, wind turbine, Rube Goldberg Device, solar cell, solar oven</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Torque, entropy, molecular energy, second law of thermodynamics, thermodynamics, thermal equilibrium, Stirling engine</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Engineering standards are built around meaningful design problems rather than phenomena. For this performance expectation, the design problem and solutions replace phenomena.

Some example design problems for HS-PS3-3:
• Use and engine to generate the most light from an LED.
• Refine a Stirling Engine to make it run for over 30mins.
• Create a solar oven that will cook an egg in 10mins.</td></tr>
</table>

	• Refine a solar cell such that it maximizes energy output.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
2. Express or complete a causal chain explaining how the device converts one form of energy into another form of energy. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.
3. Using given information, select or identify constraints that the energy converting device or solution must meet.
4. Identify evidence supporting the inference of causation that is expressed in a causal chain.
5. Using given data, propose, illustrate, or assemble a potential energy converting device (prototype) or solution.
6. Using a simulator, test a proposed energy converting prototype and evaluate the outcomes, potentially including proposing and testing modifications to the prototype.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS3-4
Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.</td><td>PS3.B: Conservation of Energy and Energy Transfer
• Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
• Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).

PS3.D: Energy in Chemical Processes
• Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.</td><td>Systems and System Models
• When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually.
• Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.

Content Limits
• Assessment is limited to investigations based on materials and tools provided to students.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Specific heat, specific heat capacity, kinetic energy, microscopic scale, macroscopic scale, molecular energy, heat conduction, heat radiation, Kelvin, Joules, calorimetry</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Entropy, root mean velocity, Boltzmann’s constant, gravitational fields, fusion, fission</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS3-4:
• The temperature of a can of soda decreases when the can is placed in a container of ice.
• Hot coffee cools down after cold cream is added to the cup.
• A scoop of ice cream begins to melt when added to cold soda in a glass.
• A foam cup has 200 grams of room temperature water after 100 grams of hot water are mixed with 100 grams of cold water.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

6. Identify, make, plan, and/or record observations/outcome data concerning changes in substances' properties in order to provide evidence of transfer of thermal energy within a closed system.
7. Organize, arrange, and/or generate/construct graphs, flowcharts, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations among observations and data concerning transfer of thermal energy within a closed system, and/or the boundaries of a closed system in which thermal energy is transferred.
8. Describe, analyze, and/or summarize data (e.g., using illustrations and/or labels), to identify/highlight trends, perform calculations and other mathematical analyses, and identify patterns or correlations among observations and data concerning the transfer of thermal energy within a closed system.
9. Use evidence to identify the boundaries of a closed system in which thermal energy is transferred.
10. Identify patterns or evidence in the data that support inferences related to the transfer of thermal energy within a closed system.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS3-5
Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>PS3.C: Relationship Between Energy and Forces
• When two objects interacting through a field change relative position, the energy stored in the field is changed.</td><td>Cause and Effect
• Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of models could include: Drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other

Content Limits
• Assessment is limited to systems containing two objects
• <u>Students do not need to know:</u> Gauss' Law, Ampere's Law, Faraday's Law or anything that requires in depth knowledge of the electromagnetism as a unified force.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Electric current, acceleration, net force, newton's second law of motion, inertia, velocity, magnet, electrical energy, magnetic force, attraction, repulsion, electromagnet, Coulomb's law, electric/magnetic field, potential energy, kinetic energy</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Semiconductor, superconductor, torque, Gauss' Law, Ampere's Law, Lorentz force, Faraday's Law, Lenz's Law</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS3-5:
• Two magnets are held close together such that they attract each other. When the magnets are further away from each other it is easier to keep them apart.
• A light bulb connected to a circuit with a battery lights up. When a stronger battery is placed in the circuit, the light bulb becomes brighter.
• A magnet rotates when placed in a magnetic field perpendicular to the magnet. When the magnet is brought close to the source of the magnetic field, it rotates faster.
• A water molecule is placed in an electric field. After it is released, it begins to rotate. After it rotates 90 degrees, it stops rotating.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon.</td></tr>
<tr><td colspan="4">2. Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing how the forces between the objects and the energy of each object changes. This <u>does not</u> include labeling an existing diagram.*</td></tr>
<tr><td colspan="4">3. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.*</td></tr>
</table>

4. Make predictions about the effects of changes in orientation of objects, distance between objects or size of magnetic and electric charges on the forces between objects and the energy of each object. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.**
5. Describe, select, or identify the relationships among components of a model that describe or explains the behavior of electric and magnetic fields and/or how that affects the forces between objects and the energy of the objects.
6. Identify missing components, relationships, or other limitations of the model.

*denotes those task demands which are deemed appropriate for use in stand-alone development
**TD 4 can only be used with TD2

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS4-1
Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.</td><td>PS4.A: Wave properties
• The wavelength and frequency of a wave are related to each other by the speed of travel of the wave, which depends on the type of wave and the media through which it is passing.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through Earth.

Content Limits
• Assessment is limited to algebraic relationships and describing those relationships qualitatively.
• Students are not expected to produce equations from memory, like Snell’s Law, but the concepts and relationships should be assessed.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Simple wave, vacuum, electromagnetic radiation, radiation, wave source, index of refraction, Snell’s Law, angle of incidence, angle of reflection, normal at the point of incidence, critical angle, interface.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Clausius–Mossotti relation, dielectric constant, Fermat’s principle, phase velocity, permittivity, permeability.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS4-1:
• A person uses their car horn in an effort to attract the attention of their friend who is swimming in a pool a short distance away. The friend hears only muffled noises.
• A person opens their curtains so that the sun shines in the window. A diamond in their necklace begins to sparkle brightly.
• An earthquake occurs in Japan. The vibrations are recorded in Brazil, but not in Miami.
• A person sees a fish through the glass wall of a rectangular fish tank. The person moves and looks through the end of the tank. The fish appears to be in a different place.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Make calculations using given data to calculate or estimate relationships among the frequency, wavelength, speed of waves, and the media that they travel in.</td></tr>
<tr><td colspan="4">2. Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate relationships among the frequency, wavelength, speed of waves, and the media that they travel in.</td></tr>
<tr><td colspan="4">3. Calculate or estimate properties or relationships among the frequency, wavelength, and speed of waves in various media based on data from one or more sources.</td></tr>
</table>

4.	Compile, from given information, the particular data needed for a particular inference about a relationship among the frequency, wavelength, speed of waves, and the media they travel in. This can include sorting out the relevant data from the given information.
5.	Use quantitative or abstract reasoning to support a claim/explanation about a particular relationship between the velocity, wavelength, and frequency.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS4-2
Evaluate questions about the advantages of using a digital transmission and storage of information.</td></tr>
<tr><td>Dimensions</td><td>Asking Questions and Defining Problems
• Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.</td><td>PS4.A: Wave Properties
• Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.</td><td>Stability and Change
• Systems can be designed for greater or lesser stability.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly.
• Disadvantages could include issues of easy deletion, security, and theft.

Content Limits
• Assessment does not include the specific mechanism of any given device.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Wave pulse, Wi-Fi device, binary, capacity, civilization, interdependence, degradation, emit, pixel, suitability, performance, analog, digital, progress, vacuum, electromagnetic radiation, computer, machine, radio wave, USB, bit, byte, discrete vs. continuous, decode, encode.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Analog jack, HDMI, router, impedance, granularity, bandwidth.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS4-2:
• A person uses e-mail to back up all of their personal data.
• A person is reading some science papers that were written in 1905 and wonders how people got so much great research done before the internet was invented.
• One day in June 2009 a person noticed that their old analog television stopped broadcasting their favorite television channel.
• A person stays in constant contact with all of their friends and relatives using their cell phone.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify or construct an empirically testable question(s) based on advantages and disadvantages associated with the phenomenon. In addition to other plausible distractors, distractors may include non-testable (“nonscientific”) questions.</td></tr>
<tr><td colspan="4">2. Make and/or record observations about the factors that affect digitally stored or transmitted data.</td></tr>
<tr><td colspan="4">3. Assemble or complete an illustration, flow chart, or graph based on an empirically testable question that is capable of identifying clear advantages or disadvantages associated with digital transmission and storage of information in the phenomenon.</td></tr>
<tr><td colspan="4">4. Select or describe conclusions relevant to a question posed and supported by the data, especially inferences about causes and effects.</td></tr>
</table>

5.	Make predictions about the phenomenon derived from the questions. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors. Predict outcomes when properties are changed, given the inferred cause and effect relationships.
6.	Compile, from given information, the particular data needed for a particular inference about the advantages/disadvantages. This can include sorting out the relevant data from the given information.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS4-3
Evaluate the claims, evidence and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Evaluate the claims, evidence and reasoning behind currently accepted explanations or solutions to determine the merits of arguments</td><td>PS4.A: Wave Properties
• Waves can add or cancel one another as they cross, depending on their relative phase (i.e. relative position of peaks and troughs of waves), but they emerge unaffected by each other. (Boundary: the discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up).

PS4.B: Electromagnetic Radiation
• Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.</td><td>Systems and System Models
• Models (e.g., physical, mathematical and computer models) can be used to simulate systems and interactions – including energy, matter and information flows – within and between systems at different scales.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on how experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Assessment should only test the qualitative aspect of the wave model vs. particle model.
• Examples of a phenomenon could include:
    o Resonance
    o Interference
    o Diffraction
    o Photoelectric Effect

Content Limits
• Assessment does not include using Quantum Theory
• Assessment does not include in depth calculations
• <u>Students do not need to know:</u> Specific types of electromagnetic radiation and their wavelengths/frequencies</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Interference, diffraction, refraction, photoelectric effect, emission, absorption, brightness, resonance, transmission, visible light, transverse wave</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Doppler effect for light (redshift), microwave radiation, ultraviolet radiation, ionize, infrared radiation, wave-particle duality, quantum, quanta, x-ray, gamma rays, radio waves, oscillations, electrostatic induction, Planck’s equation, Planck’s constant, magnetic dipole, electric dipole,</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS4-3:
• When light hits a metal, a stream electrons are ejected from the metal. When the color of the light pointed at the metal changes, the kinetic energy of the stream of electrons changes.</td></tr>
</table>

<table>
<tr><td></td><td>Light is made to pass through two small slits on a piece of dark construction paper. The light that goes through the slits is then projected on a second piece of dark of construction. A pattern of bright and dark bands is seen on the second piece of dark construction paper.
The emission spectra of Hydrogen is completely black but for 4 discrete lines violet, blue, green and red color.
A red laser is pointed at a glass prism. The light bends as it goes through the prism. A violet laser is then pointed at the glass prism and the light bends more than the light from the red laser.</td></tr>
<tr><td colspan="2">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="2">Task Demands</td></tr>
<tr><td colspan="2">1. Based on the provided data or information, identify the explanation that describes light behaves like a particle and or behaves like a wave.</td></tr>
<tr><td colspan="2">2. Identify and/or explain the claims, evidence, and reasoning supporting the explanation that light can behave like a particle or a wave, and why certain evidence is best explained by only one of these models.</td></tr>
<tr><td colspan="2">3. Identify and/or describe additional relevant evidence not provided that would support or clarify the explanation of how light can behave like a particle or a wave.</td></tr>
<tr><td colspan="2">4. Evaluate the strengths and weaknesses of a claim to explain which pieces of evidence support the fact that light behaves as a particle or a wave.</td></tr>
<tr><td colspan="2">5. Analyze and/or interpret evidence and its ability to support the explanation that light can behave as both a wave and a particle.</td></tr>
<tr><td colspan="2">6. Provide and/or evaluate reasoning to support the explanation that light can behave as both a wave and a particle and that some evidence is only supported by one of the models.</td></tr>
</table>

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS4-4
Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating Information
• Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible.</td><td>PS4.B: Electromagnetic Radiation
• Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.</td><td>Cause and Effect
• Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation.
• Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.

Content Limits
• Assessment is limited to qualitative descriptions.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Interference, diffraction, refraction, photoelectric effect, emission, absorption, brightness, resonance, photon, visible light, transverse wave, phase, transparent, light scattering, light transmission, radio wave, visible light, electric potential, gamma ray, infrared radiation, ionize, microwave, ohm, photoelectric, ultraviolet,</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Doppler effect for light (redshift), microwave radiation, ultraviolet radiation, infrared radiation, wave-particle duality, quantum, quanta, x-ray, gamma rays, oscillations, electrostatic induction, Planck’s equation, Planck’s constant, magnetic dipole, electric dipole</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS4-4:
• A student places a glass bowl filled with soup in a microwave. After a minute in the microwave, the soup is hotter than the glass bowl.
• A lit candle is placed at one end of a tube filled with carbon dioxide. A student standing at the other end of the tube can see the candle’s flame. When looking through a monitor that looks at the infrared radiation emitted by the flame, the student can no longer see the candle’s flame.
• Astronauts aboard the International Space Station are exposed to a different amount of ultraviolet radiation from the sun than humans on Earth.
• In 2020, NASA is sending a rover to Mars with multiple materials on it in order to test whether or not they can be used as space suits for future Mars travelers. Orthofabric was chosen to be sent on the mission, while Spectra was not.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

1.	Analyze and/or interpret scientific evidence from multiple scientific/technical sources including text, diagrams, charts, symbols, mathematical representations that provide evidence of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.*
2.	Identify relationships or patterns in scientific evidence to describe how different frequencies of electromagnetic radiation effect matter when absorbed.
3.	Illustrate, graph, or identify relevant features or data that can be used to communicate information about the effect that different frequencies of electromagnetic radiation have on matter when it is absorbed.
4.	Synthesize an explanation for the effects of electromagnetic radiation on matter when absorbed that incorporates the scientific evidence from multiple sources.*
5.	Evaluate the validity, credibility, accuracy, relevancy and/or possible bias of scientific/technical sources.
6.	Identify the cause and effect reasoning in a claim from the sources, including the extrapolations to larger scales from cause and effect relationships of mechanisms at small scales (e.g. extrapolating from the effect of a particular wavelength of radiation on a single cell to the effect of that wavelength on the entire organism).

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS4-5
Communicate technical information how some technological devices use the principles of wave behavior and wave interaction with matter to transmit and capture information and energy.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating Information
• Communicate technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).</td><td>PS3.D: Energy in Chemical Processes
• Solar cells are human-made devices that likewise capture the sun’s energy and produce electrical energy. (secondary)

PS4.A: Wave Properties
• Information can be digitalized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.

PS4.B: Electromagnetic Radiation
• Photoelectric materials emit electrons when they absorb light of a high enough frequency.

PS4.C: Information Technologies
• Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.</td><td>Cause and Effect
• Systems can be designed to cause a desired effect.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples could include solar cells capturing light and converting it to electricity, medical imaging, and communications technology.

Content Limits
• Assessments are limited to qualitative information.
• Assessment does not include band theory.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">refraction, reflection, infrared, electromagnetic spectrum, constructive wave, destructive wave, restoring, periodic motion, mechanical wave, interference, velocity, diffraction, standing wave, nodes, angle of incidence, rarefaction, superposition, medium, longitudinal wave, transverse wave, standing wave, ultrasound, dispersion, intensity, prism, resonance, radar, sonar, virtual image, real image</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Constructive interference, destructive interference, light ray, total internal reflection</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Engineering Standards are built around meaningful design problems rather than phenomena. For this performance expectation, the design problem and solutions replace phenomena.

Some example design problems and/or solutions for HS-PS4-5:</td></tr>
</table>

	• When using light detection and ranging (LiDAR) over a forested area the light reflects off multiple surfaces and affects the accuracy of elevation models. • Solar cells only capture about 20% of the energy from the sun. • Marine radar is mounted to the front of ships used for collision avoidance. Occasionally the radar can distort the coast line and report a straight coastline when it is curved. • Water reflects radar, blanking out entire regions of radar screens.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Analyze and interpret scientific evidence from multiple scientific/technical sources including text, diagrams, charts, symbols, mathematical representations that provide evidence of how devices use wave behavior, the absorption of photons, and the production of electrons to solve problems.
2. Identify relationships or patterns in scientific evidence to describe how waves are used to produce, transmit, and capture signals in electronic devices.
3. Illustrate, graph, or identify relevant features or data that can be used to communicate wave information and
4. Synthesize an explanation for the function and properties of designed materials that incorporates the scientific evidence from multiple sources.
5. Evaluate the validity, credibility, accuracy, relevancy and/or possible bias of scientific/technical sources.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS1-1
Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>LS1.A: Structure and Function
• Systems of specialized cells within organisms help them perform the essential functions of life.
• All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.</td><td>Structure and Function
• Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and the connections of these components in order to solve problems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Content Limits
• Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Nucleus, chromosome, DNA, nucleated cell, transcription, double helix, adenine, guanine, cytosine, thymine, deoxyribose, phosphate, hydrogen bond, nucleotide base, mRNA, amino acid, translation</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">primary, secondary, tertiary protein structure, tRNA, ribosome.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Sample phenomena for HS-LS1-1:
• Sweat glands cool the body by releasing sweat onto the skin’s surface. A protein transports salt to help carry the water to the skin’s surface. In some individuals, the salt is not reabsorbed and is left on the skin.
• When a blood vessel is cut, several proteins act to form a blood clot. This blood clot helps to stop the loss of blood from the body. In some individuals, when a blood vessel is cut, a blood clot does not form.
• During cell division, a copy of DNA in the cell is made. Sometimes mistakes are made in the DNA copy that are corrected by specific proteins. In some cells, when those mistakes in the DNA are not corrected, uncontrolled cellular division results.
• After a person eats, sugars from food are absorbed from the bloodstream into the body’s cells. Insulin—a polypeptide hormone—allows those cells to absorb glucose from the bloodstream. In some individuals, sugars are not absorbed into the body’s cells and are left in the bloodstream.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Describe the cause and effect relationship between a DNA sequence and the structure/function of a protein. This may include indicating the directions of causality in a model or completing a cause and effect chain.</td></tr>
</table>

2.	Describe, identify, or select evidence that supports or contradicts a claim about the role of DNA in causing the phenomenon. The evidence may be obtained from valid source(s) or might be generated by students using a simulation.
3.	Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes to a DNA sequence in protein structure and function. Predictions may be selected from a collection of possibilities, including distractors, or they might be illustrated or described in writing.
4.	Use evidence to construct an explanation of how protein structure and subsequent function depend on a DNA sequence.
5.	Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS1-2
Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>LS1.A: Structure and Function
• Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.</td><td>Systems and System Models
• Models (e.g., physical, mathematical, and computer models) can be used to simulate systems and interactions — including energy, matter, and information flows — within and between systems at different scales.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.

Content Limits
• Assessment does not include interactions and functions at the molecular or chemical reaction level (e.g., hydrolysis, oxidation, reduction, etc.).
• Assessment does not include mutations in genes that could contribute to modified bodily functions.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Circulatory, respiratory, digestive, excretory, nervous, immune, integumentary, skeletal, muscle, reproductive, external stimuli, cell, tissue, organ,</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Synaptic transmission, neuron, neurotransmitter, biofeedback, hormonal signaling.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS1-2:
• After a healthy person eats a large meal, both their blood pressure and heart rate increase.
• When a normal adult male exercises, both his breathing rate and heart rate increase.
• The area around a person’s skin where a small scab has formed feels warm to the touch.
• Skin surface capillaries dilate when a person feels hot.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Assemble or complete an illustration or flow chart that is capable of representing how structures in two (or more) body systems interact to carry out normal, necessary bodily functions. This <u>does not</u> include labeling an existing diagram.*</td></tr>
<tr><td colspan="4">2. Using the developed model, identify and describe the relationships between the structures and their coordinated functions in two (or more) body systems.</td></tr>
<tr><td colspan="4">3. Using the developed model, show that interacting systems have a hierarchical organization and provide specific functions within the body at those specific levels or organization.*</td></tr>
</table>

4.	Make predictions about, or generate explanations for, how additions/substitutions/removal of certain components in the model can interrupt or change the relationships between those components and, thus, the bodily functions carried out by those structures in two (or more) body systems.
5.	Given models or diagrams of hierarchical organization of interacting systems, identify the components and the mechanism in each level of the hierarchy OR identify the properties of the components that allow those functions to occur.
6.	Identify missing components, relationships, or other limitations of the model.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS1-3
Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence. In the design decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.</td><td>LS1.A: Structure and Function
• Feedback mechanisms maintain a living system’s internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.</td><td>Stability and Change
• Feedback (negative or positive) can stabilize or destabilize a system.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.

Content Limits
• Assessment does not include the cellular processes involved in the feedback mechanism.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Equilibrium, steady state, stable state, balanced state, stimulus, receptor, biotic factor, abiotic factor, external environment, internal environment, muscle, nerve, hormone, enzyme, chemical regulator, gland, system, metabolism, disturbance, fluctuation, maintenance, concentration, hibernation, convection, conduction, radiation, evaporation.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Effector, osmoregulation, conformer, set point, sensor, circadian rhythm, acclimatization, thermoregulation, endothermic, ectothermic, integumentary system, countercurrent exchange, bioenergetics, basal metabolic rate, standard metabolic rate, torpor, poikilotherm, homeotherm, countercurrent heat exchange.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS1-3:
• Fruit ripeness (positive feedback loop):
  ○ In nature, a tree or bush will suddenly ripen all of its fruits or vegetables without any visible signal.
• Human blood sugar concentration (negative feedback loop):
  ○ The liver both stores and produces sugar in response to blood glucose concentration.
  ○ The pancreas releases either glucagon or insulin in response to blood glucose concentration.
• Sunning lizards (negative feedback loop):
  ○ Lizards sun on a warm rock to regulate body temperature.
• Thermoregulation in dolphins due to counter-current arrangement of veins around arteries (negative feedback loop):
  ○ The counter-current system minimizes the loss of heat incurred when blood travels to the different parts of dolphins’ bodies.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

1.	Identify the outcome data that should be collected in an investigation to provide evidence that feedback mechanisms maintain homeostasis. This could include measurements and/or identifications of changes in the external environment, the response of the living system, stabilization/destabilization of the system's internal conditions, and/or the number of systems for which data are collected.
2.	Make and/or record observations about the external factors affecting systems interacting to maintain homeostasis, responses of living systems to external conditions, and/or stabilization/destabilization of the systems' internal conditions.*
3.	Identify or describe the relationships, interactions, and/or processes that contribute to and/or participate in the feedback mechanisms maintaining homeostasis that lead to the observed data.
4.	Using the collected data, express or complete a causal chain explaining how the components of (a) mechanism(s) interact in response to a disturbance in equilibrium in order to maintain homeostasis. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.*
5.	Evaluate the sufficiency and limitations of data collected to explain the cause and effect mechanism(s) maintaining homeostasis.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

Performance Expectation	**HS-LS1-4** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.		
Dimensions	**Developing and Using Models** • Use a model based on evidence to illustrate the relationships between systems or between components of a system.	**LS1.B: Growth and Development of Organisms** • In multicellular organisms, individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.	**Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.
Clarifications and Content Limits	**Clarification Statements** • Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis. **Content Limits** • <u>Students do not need to know</u>: Specific names of the stages of mitosis – Interphase, G1 phase, S phase, G2 phase, prophase, metaphase, anaphase, telophase, cytokinesis.		
Science Vocabulary Students Are Expected to Know	Nucleus, chromosome, sister chromatids, sperm cell, egg cell, fertilize, genome, gene, differential gene expression, cellular differentiation, cellular division, cytoplasm, daughter cell, parent cell, somatic cell, cell cycle, homologous, haploid, diploid, DNA.		
Science Vocabulary Students Are Not Expected to Know	Spindle, metaphase plate, cleavage furrow, chromatin modification, transcription regulation initiation, enhancers, transcription factors, post-transcriptional regulation; noncoding RNAs, cytoplasmic determinants, inductive signals, chiasmata, kinetochore, microtubule.		
Phenomena			
Context/ Phenomena	Some example phenomena for HS-LS1-4: • Genomic sequencing of a parent cell and one of its daughter cells reveals that both have the same genetic makeup. • At the end of an hour, approximately 30,000 skin cells were shed by a person, but a loss of mass was not noticeable. • Ears and noses can be grown from stem cells in laboratory. • Plant cells in a root tip longitudinal cross section are different sizes and shapes.		
This Performance Expectation and associated Evidence Statements support the following Task Demands.			
Task Demands			
1. Assemble or complete an illustration or flow chart that is capable of representing how a parent (somatic) cell is formed through fertilization, undergoes cellular division, forming daughter cells, and how those daughter cells contain all genetic material from the parent cells but differentiate via gene expression necessary. This does **not** include labeling an existing diagram.*			

2.	Using the model, identify and describe the relationship between the amount and composition of the genetic material that daughter cells receive from parent cells.
3.	Using the model, show that in multicellular organisms, different cell types arise from differential gene expression, not because of dissimilar genetic material within the cell's nucleus.
4.	Use a model of cellular division and differentiation to explain/illustrates the relationships between components that allow multicellular organisms to grow and carry out specific and necessary functions.*
5.	Given models or diagrams of cellular division and differentiation, show that cells form tissues and organs that have specific structures and interact to carry out specific and necessary functions.
6.	Identify missing components, relationships, or other limitations of the model.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS1-5
Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Use a model based on evidence to illustrate the relationship between systems or between components of a system.</td><td>LS1.C: Organization for Matter and Energy Flow in Organisms
• The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.</td><td>Energy and Matter
• Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms.
• Examples of models could include diagrams, chemical equations, and conceptual models.

Content Limits
• Assessment does not include specific biochemical steps or cell signaling pathways.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Organic, hydrocarbon, net transfer, chloroplast, chlorophyll, cytoplasm, mitochondria, vacuole, nucleus, protein, ATP, amino acid, autotroph(s), heterotroph(s), algae</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Thylakoid, NADP(H/$^+$), Calvin cycle, carbon fixation, redox reactions, electron transport chain, oxidative phosphorylation, photoautotroph(s), mesophyll, stomata, stroma, thylakoids, thylakoid membrane, light reactions, carotenoids, cytochrome complex, C_3 pants, C_4 plants</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS1-5:
• A maple tree in Washington state survives in the winter after losing all of its leaves.
• The waters of the Laguna Grande lagoon in Puerto Rico give off a bluish-green glow at night when disturbed.
• On the sill of a stained glass window, a soy plant behind the red glass panel grew taller than a soy plant behind the green glass panel.
• In a parking lot in the city of Bordeaux, France a tank filled with algae produces a green light.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Assemble or complete, from a collection of potential model components and distractors, an illustration or flow chart that is capable of representing the transformation of light energy into stored chemical energy.</td></tr>
<tr><td colspan="4">2. Use a model to identify and describe the relationships in terms of matter and/or energy between the reactants and the products of photosynthesis.*</td></tr>
<tr><td colspan="4">3. Use a model to show the transfer of matter and flow of energy between an organism and its environment during photosynthesis.*</td></tr>
</table>

4.	Make predictions about how additions/substitutions/removals of model components affect the transformation of light energy into stored chemical energy.*
5.	Sort relevant from irrelevant information to support a model that demonstrates how sugar and oxygen are produced by carbon dioxide and water through the process of photosynthesis.
6.	Given models or diagrams of photosynthesis, identify the components and the mechanism in each scenario OR identify the properties of the components that allow photosynthesis to occur.*
7.	Identify missing components, relationships, or other limitations of a model intended to show how photosynthesis transforms light energy into stored chemical energy.
8.	Describe changes of energy and matter that occur in a system due to photosynthesis.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS1-6
Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>LS1.C: Organization for Matter and Energy Flow in Organisms
• Sugar molecules formed contain carbon, hydrogen, and oxygen. Their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used, for example, to form new cells.
• As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.</td><td>Energy and Matter
• Changes of energy and matter in a system can be described as energy and matter flowing into, out of, and within that system.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on using evidence from models and simulations to support explanations.

Content Limits
• Assessment does not include the details of the specific chemical reactions or identification of macromolecules.
• <u>Students do not need to know:</u> Specific biochemical pathways and processes. Specific enzymes, oxidation-reduction</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Hydrocarbon, carbohydrate, amino acid, nucleic acid, DNA, ATP, lipid, fatty acid, ingestion, rearrangement, stable, open system.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Endothermic reaction, exothermic reaction, aerobic respiration, oxidation, reduction, oxidation-reduction reaction, glycolysis, citric acid cycle, electron transport chain.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS1-6:
• Hagfish produce and are covered in a thick layer of protective slime.
• The black widow spider's silk is several times as strong as any other known spider silk, making it about as durable as Kevlar.
• The female silk moth, releases a pheromone that is sensed by the male's feather-like antennae, inducing his excited fluttering behavior.
• The bombardier beetle release a boiling, noxious, pungent spray that can repel potential predators.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

1.	Describe, identify, or select evidence supporting or contradicting a claim that sugar molecules containing organic elements (e.g., carbon, hydrogen, and oxygen) that are ingested by an organism are broken down and rearranged via chemical reactions to form proteins, lipids, and nucleic acids.
2.	Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses.
3.	Express or complete a description of the flow of energy and/or matter within and between living systems. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.*
4.	Articulate, describe, or select the relationships, interactions, reactions and/or processes to be explained. This may entail sorting relevant from irrelevant information or features of the reactants and products.*
5.	Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes in the amount and types of organic molecules ingested and the amount and type of products formed within a living system.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS1-7
Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Use a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>LS1.C: Organization for Matter and Energy Flow in Organisms
• As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products
• As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.</td><td>Energy and Matter
• Energy cannot be created or destroyed—it only moves between one place and another, between objects and/or fields, or between systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statement
• Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.

Content Limits
• Students aren’t expected to identify the steps or specific processes involved in cellular respiration.
• Assessment does not include mechanisms of cellular respiration (enzymatic activity, oxidation, molecular gradients, etc.).
• <u>Students do not need to know:</u> enzymes, ATP synthase, metabolism, biochemical pathways, redox reactions, molecular transport.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">ATP, chemical bonds, energy transfer, glycolysis, enzymes, mitochondria, cytosol, cytoplasm, nitrogen, adenine, phosphate, amino acid.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Biochemical, fatty acids, oxidizing agent, electron acceptor, biosynthesis, locomotion, phosphorylation, electron transport chain, chemiosmosis, pyruvate, pentose.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS1-7:
• A young plant is grown in a bowl of sugar water. As it grows, the amount of sugar in the water decreases.
• A bacterial colony in a petri dish is continually provided with sugar water. Over the course of a few days, the bacteria grow larger. When sugar water is no longer provided, the colonies shrink and some disappear.
• A person feels tired and weak before eating lunch. After eating some fruit, the person feel more energetic and awake.</td></tr>
</table>

	• An athlete completing difficult training feels that her muscles recover and repair faster when she eats more food in a day, compared to when she ate less food in a day.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Assemble or complete an illustration or flow chart that is capable of representing the transformation of food plus oxygen into energy and/or new compounds. This *does not* include labeling an existing diagram.
2. Using the developed model, identify and describe the relationships between the reactants of the transformation and the products of the transformation.*
3. Using the developed model, show that matter and energy are only rearranged during cellular respiration, but never created or destroyed.
4. Make predictions about how additions/substitutions/removals of certain components can maintain/destroy the balance of the food plus oxygen → energy/new compounds reaction.*
5. Given models or diagrams of cellular respiration, identify the components and the mechanism in each scenario OR identify the properties of the components that allow cellular respiration to occur.
6. Identify missing components, relationships, or other limitations of the model.
7. Describe, select, or identify the relationships among components of a model that describe or explain cellular respiration.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS2-1
Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematical and Computational Thinking
• Use mathematical and/or computational representations of phenomena or design solutions to support explanations</td><td>LS2.A: Interdependent Relationships in Ecosystems
• Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from challenges such as predation, competition and disease. Organisms would have the capacity to produce populations of greater size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.</td><td>Scale, Proportion, and Quantity
• The significance of a phenomenon is dependent on the scale, proportion, and quantity involved.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors, including boundaries, resources, climate, and competition.
• Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.
• Examples of mathematical representations include finding the average, determining trends, and using graphic comparisons of multiple sets of data.

Content Limits
• Assessment does not include deriving mathematical equations to make comparisons.
• <u>Students do not need to know:</u> Calculus/advanced mathematics (e.g., exponential growth and decay).</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Predation, interdependent, disturbance, equilibrium of ecosystems, fluctuation, stable, biotic, abiotic, sustain, anthropogenic, overexploitation, urbanization, population, emigrants, immigrants, exponential, generation, rebounding, limiting resources, logistic, competition, negative feedback, population control.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Dispersion, demography, survivorship curve (J or S), reproductive table, semelparity, iteroparity, metapopulation, demographic transition, resource partitioning, Shannon diversity, biomanipulation, density dependent selection (K-selection), density independent selection (r selection), intrinsic factors.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-1:
• On Ngorogoro Crater in Tanzania in 1963, a scientist sees that there are much fewer lions than there were on previous visits.
• On St. Matthew Island, reindeer were introduced in 1944, but today no reindeer can be found on the island.
• In Washington State, more harbor seals are present today than in the past.
• In Alaska, you can see many more brown bears in Lake Clark National Park than in Denali National Park.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
</table>

Task Demands
1. Make calculations using given data to calculate or estimate factors affecting the carrying capacity of an ecosystem.*
2. Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate factors affecting the carrying capacity of ecosystems of different scales.*
3. Calculate or estimate properties of or relationships between factors affecting the carrying capacity of an ecosystem based on data from one or more sources.
4. Compile, from given information, the data needed for a particular inference about factors affecting the carrying capacity of an ecosystem. This can include sorting out the relevant data from the given information and representing the data through graphs, charts, and/or histograms.
5. Use quantitative or abstract reasoning to make a claim about the factors that affect the carrying capacity of an ecosystem.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

Performance Expectation	**HS-LS2-2** Use mathematical representations to support and revise explanations, based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.		
Dimensions	**Using Mathematical and Computational Thinking** • Use mathematical representations of phenomena or design solutions to support and revise explanations.	**LS2.A: Interdependent Relationships in Ecosystems** • Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits results from factors such as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of greater size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** • A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient) as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.	**Scale, Proportion, and Quantity** • Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.
Clarifications and Content Limits	**Clarification Statements** • Examples of mathematical representations include finding the average, determining trends, and using graphic comparisons of multiple sets of data. **Content Limits** • Assessment is limited to provided data. • <u>Students do not need to know</u>: Calculus/advanced mathematics (e.g., exponential growth and decay)		
Science Vocabulary Students Are Expected to Know	Carrying capacity, anthropogenic changes, overexploitation, extinction, demographic, population pyramid, deforestation, habitat fragmentation, sustainable, abiotic factor, biotic factor, species richness, symbiosis, niche, fragile ecosystem, biodiversity index, zero population growth, density, dispersion, immigration, emigration, limiting factor		
Science Vocabulary Students Are Not Expected to Know	Water regime, direct driver, eutrophication, species evenness, range of tolerance, realized niche, niche generalist, niche specialist, edge habitat, endemic species, logistic growth model, exponential population growth, mark-recapture method, territoriality, demography, cohort, survivorship curve, reproductive table, life history, semelparity, iteroparity, K-selection, r-selection, dieback.		

Phenomena	
Context/ Phenomena	Some example phenomena for HS-LS2-2: • After brown tree snakes were accidentally introduced to Guam in the 1950s, 11 native bird species went extinct. • When European settlers decreased the wolf population for safety, deer populations thrived and overconsumed native plant species. • California's Central Valley can support fewer waterfowl in the winter during drought. • The cones of Lodgepole pines do not release their seeds until a fire melts the resin that keeps them sealed.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Make simple calculations using given data to calculate or estimate factors affecting biodiversity and populations in ecosystems.
2. Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate factors affecting biodiversity and populations in ecosystems of different scales.
3. Calculate or estimate properties of or relationships between factors affecting biodiversity and populations in ecosystems based on data from one or more sources.
4. Compile, from given information, the data needed for a particular inference about factors affecting biodiversity and populations in ecosystems. This can include sorting out the relevant data from given information.
5. Construct an explanation regarding the relationship between biodiversity and populations in ecosystems of different scales using the given, calculated, or compiled information.
6. Revise or evaluate a given explanation of the relationship between biodiversity and populations in ecosystems of different scales based on the given, calculated, or compiled information.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS2-3
Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, and peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
• Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for the processes.</td><td>Energy and Matter
• Energy drives the cycling of matter within and between systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.
• Emphasis is on conceptual understanding that the supply of energy and matter restricts a system’s operation; for example, without inputs of energy (sunlight) and matter (carbon dioxide and water), a plant cannot grow.

Content Limits
• Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.
• Students do not need to know: lactic acid vs. alcoholic fermentation, chemical equations for photosynthesis, cellular respiration, or fermentation.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Organic compound synthesis, net transfer, biomass, carbon cycle, solar energy</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Lactic acid fermentation, alcoholic fermentation, glycolysis, Kreb’s cycle, electron transport chain.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-3:
• After running for a long period of time, human muscles develop soreness and a burning sensation, and breathing rate increases.
• Bread baked with yeast looks and tastes differently than bread that is baked without yeast.
• A plant that is watered too much will have soft, brown patches on their leaves and will fail to grow.
• Cyanobacteria differ from other bacteria in that cyanobacteria appear blue-green in color and also lack flagella.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Describe, identify, or select evidence supporting or contradicting a claim about the role of photosynthesis and aerobic and anaerobic respiration in the cycling of matter and energy in an ecosystem.</td></tr>
</table>

2. Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses.
3. Express or complete a description of the flow of energy and/or matter between organisms. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause-and-effect chains.*
4. Articulate, describe, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features of the reactants and products.*
5. Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes in environmental conditions on the flow of matter and energy between organisms.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS2-4
Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematical and Computational Thinking
• Use mathematical representations of phenomena, or design solutions to support claims.</td><td>LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
• Plants or algae from the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.</td><td>Energy and Matter
• Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another, and that matter and energy are conserved as matter cycles and energy flows through ecosystems.
• Emphasis is on atoms and molecules—such as carbon, oxygen, hydrogen, and nitrogen—being conserved as they move through an ecosystem.

Content Limits
• Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.
• <u>Students do not need to know</u>: the specific biochemical mechanisms or thermodynamics of cellular respiration to produce ATP or of photosynthesis to convert sunlight energy into glucose.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Interdependent, nutrient, hydrocarbon, transfer system, equilibrium of ecosystems, decomposer, producer, ATP, solar energy, predator-prey relationship, trophic level</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Detritivore, denitrification, thermodynamics, nitrogen fixation, biogeochemical cycle, anaerobic process.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-4:
• In the 6,000-hectare rainforest of San Lorenzo, Panama, there are 312 arthropods for every mammal, including humans.
• In Silver Springs, Florida, the biomass of plants is 809 g/m^2, while the biomass of large fish is 5 g/m^2.</td></tr>
</table>

	• A herd of grazing caribou in the Seward Peninsula of Alaska are seen eating the leaves of birch trees in July. In December, they are seen eating tree lichen. • A pine tree growing in a forest remains in one location throughout its lifetime. A fox in the same forest moves around every day of its life.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Calculate or estimate changes or differences in matter and energy between trophic levels of an ecosystem. **
2. Illustrate, graph, or identify a mathematical model describing changes in stored energy through trophic levels of an ecosystem.**
3. Compile and interpret data from given information to establish the relationship between organisms at different trophic levels.*
4. Use quantitative or abstract reasoning to make a claim about the cycling of matter and flow of energy through the trophic levels of an ecosystem. This may include sorting relevant from irrelevant information.*
5. Identify and describe the components of a mathematical representation of an ecosystem that could include relative quantities related to organisms, matter, energy, and the food web of that ecosystem.

*denotes those task demands which are deemed appropriate for use in stand-alone item development
**TDs 1 and 2 may be used for stand-alones in combination with TD3 and TD4.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS2-5
Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop a model based on evidence to illustrate the relationships between systems or components of a system.</td><td>LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
• Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.

PS3.D: Energy in Chemical Processes
• The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary)</td><td>Systems and System Models
• Models (e.g., physical, mathematical, or computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of models could include simulations and mathematical models.

Content Limits
• Assessment does not include the specific chemical steps of photosynthesis and respiration.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Recycle, consumer, transform, organism, convert, decomposer, producer, hydrocarbon, microbes, ATP</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Endothermic reaction, exothermic reaction, free energy, hydrolysis, oxidation.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-5:
• A herd of cows grazing in a field wear balloon-like backpack devices on their backs.
• A piece of coal preserving a fossil leaf imprint is burned within the furnace of a coal-fired electrical power plant. Smoke generated from the fire escapes out of a smoke stack
• Several acres of trees are cut down and burned, generating clouds of smoke.
• Two mice die in the woods in November, one in Massachusetts and one in Florida. The Florida mouse decomposes much more quickly than the Massachusetts mouse.</td></tr>
<tr><td colspan="4" align="center">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4" align="center">Task Demands</td></tr>
<tr><td colspan="4">1. Assemble or complete an illustration or flow chart that is capable of representing how the processes of photosynthesis and cellular respiration cycle carbon by various chemical, physical, geological, and biological processes through two or more spheres (biosphere, atmosphere, hydrosphere, geosphere). This does not include labeling an existing diagram.</td></tr>
</table>

2. Using the developed model, identify and describe the relationships between the processes of photosynthesis and cellular respiration, and the coordinated functions of transferring carbon among two or more spheres (biosphere, atmosphere, hydrosphere, geosphere).
3. Using the developed model, show that photosynthesis and cellular respiration are important parts of the overall carbon cycle that transfers carbon through two or more spheres (biosphere, atmosphere, hydrosphere, geosphere).
4. Make predictions about, or generate explanations for, how substitutions of certain components in the model can interrupt or change the relationships between, or functions of, those components, thus effecting the cycling of carbon through the various spheres (biosphere, atmosphere, hydrosphere, geosphere).
5. Given models or diagrams* of the processes of photosynthesis and cellular respiration, identify the components and the mechanisms in each process that cycle carbon OR identify the properties of the components that allow those functions to occur.
6. Identify missing components, relationships, or other limitations of the model.
7. Modify/augment/add to the model to change or add steps that can alter the cycling of carbon through the various spheres (biosphere, atmosphere, hydrosphere, and/or geosphere).

*Labeled diagrams by themselves are not usually sufficient to serve as models.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS2-6
Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.</td><td>LS2.C: Ecosystem Dynamics, Functioning, and Resilience
• A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.</td><td>Stability and Change
• Much of science deals with constructing explanations of how things change and how they remain stable.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood, and extreme changes, such as volcanic eruption or sea-level rise.
• To show full comprehension of the PE, the student must demonstrate an understanding that, in a stable ecosystem, the average activity by the nutrients, decomposers, producers, primary consumers, secondary consumers, and tertiary consumers remains relatively consistent. When each of these levels has high levels of diversity, the ecosystem is stable because the group as a whole is better able to respond to pressures. However, even a healthy, diverse ecosystem is subject to extreme changes when faced with enough pressure.

Content Limits
• Assessment does not include Hardy-Weinberg equilibrium calculations.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Biosphere, biodiversity, carbon cycle, water cycle, nitrogen cycle, fluctuation, consistent, stable, equilibrium, species, emergence, extinction, niche, native, non-native, invasive, overgrazing, human impact, succession, primary succession, secondary succession.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Genetic drift, founder effect, Hardy-Weinberg, intermediate disturbance hypothesis, species-area curve.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-6:
• The populations of rabbits and deer in the Florida Everglades significantly decreased with the introduction of the Burmese python.
• Biodiversity of an area of the Amazon rainforest is affected differently in sustainable and non-sustainable lumber farms.
• After a fire, the biodiversity of a forest immediately decreases but eventually increases.
• An increase in mouse populations are observed the year after a flood but return to pre-flood numbers the following year.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Based on the provided data or information, identify the explanation that complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
2. Identify and/or explain the claims, evidence, and reasoning supporting the explanation that complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
3. Identify and/or describe additional relevant evidence not provided that would support or clarify the explanation of the complex interactions in ecosystems, factors that affect biodiversity, relationships between species and the environment, and changes in numbers of species and organisms in a stable or changing ecosystem.
4. Evaluate the strengths and weaknesses of a claim to explain the relationship of biodiversity and the environment in an ecosystem based on the evidence or data provided.*
5. Analyze and/or interpret evidence and its ability to support the explanation of the resiliency of an ecosystem in response to different levels of change.*
6. Provide and/or evaluate reasoning to support the explanation that an ecosystem remains relatively consistent when faced with modest disturbances, but it may experience extreme changes or fluctuations in biodiversity when faced with extreme disturbances.*

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS2-7
Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.</td><td>LS2.C: Ecosystem Dynamics, Functioning, and Resilience
• Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.

LS4.D: Biodiversity and Humans
• Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (secondary)

ETS1.B: Developing Possible Solutions
• When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary)</td><td>Stability and Change
• Much of science deals with constructing explanations of how things change and how they remain stable.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of human activities can include urbanization, building dams, and dissemination of invasive species.

Content Limits
• Assessment does not include physical equations describing mechanics of solutions or mechanics of engineered structures.
• <u>Students do not need to know</u>: quantitative statistical analysis, specific conditions required for failure, specifics of constructing the solution.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Carrying capacity, competition, urbanization, conversation biology, endangered species, threatened species, introduced species, overharvesting, extinction, greenhouse effect, carbon footprint</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Laws of thermodynamics, Hardy-Weinberg equilibrium, Lotka-Volterra equations, allelopathy, density-dependent population regulation, extinction vortex, minimum viable population (MVP), effective population size, movement corridor, biodiversity hot spot, zoned reserve, critical load, biological magnification, assisted migration, sustainable development.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example of phenomena for HS-LS2-7:
• The spread of cities through urbanization has destroyed wildlife habitats across the planet.
• Air pollution from driving cars has made the air unsafe to breathe in many areas.
• Dams have led to flooding of large areas of land, destroying animal habitats.
• Fishing has drastically changed marine ecosystems, removing certain predators or certain prey.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
2. Express or complete a causal chain explaining how human activity impacts the environment. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause-and-effect chains.
3. Identify evidence supporting the inference of causation that is expressed in a causal chain.
4. Use an explanation to predict the environmental outcome, given a change in the design of human technology.
5. Describe, identify, and/or select information needed to support an explanation.
6. Identify or describe relevant aspects of the problem that given design solutions for reducing the impacts of human activities on the environment and biodiversity, if implemented, will resolve or improve.
7. Using given information about the effects of human activities on the environment and biodiversity, select or identify criteria against which the solution should be judged.
8. Using given information about the effects of human activities on the environment and biodiversity, select or identify constraints that the solution must meet.
9. Evaluate the criteria and constraints, along with trade-offs, for a proposed or given solution to resolve or improve the impact of human activities on the environment and biodiversity.
10. Using given data, propose a potential solution to resolve or improve the impact of human activities on the environment and biodiversity.
11. Using a simulator, test a proposed solution to resolve or improve the impact of human activities on the environment and biodiversity and evaluate the outcomes.
12. Evaluate and/or revise a solution to resolve or improve the impact of human activities on the environment and biodiversity and evaluate the outcomes

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS2-8
Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Evaluate the evidence behind currently accepted explanations to determine the merits of arguments.</td><td>LS2.D: Social Interactions and Group Behavior
• Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence.
• Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.

Content Limits
• <u>Students do not need to know:</u>
o How to develop or analyze computer simulations and mathematical models that emulate the flocking behavior of animals.
o Individual genes or complex gene interactions determining individual animal behavior.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Behavioral ecology, cooperative behavior, altruism, environmental stimuli, circadian clock, communication, foraging, optimal foraging model, energy costs and benefits, competition, predator, mutual protection, packs</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Fixed action pattern, pheromones, innate behavior, learning, imprinting, spatial learning, social learning, associative learning, problem solving, cognition, game theory, agonistic behavior, mating behavior, mating systems, parental care, mate choice, male competition for mates, reciprocal altruism, shoaling</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-8:
• Several hundred naked mole rats are observed living together in a colony. However, only one large naked mole rat is observed reproducing, while the others in the colony bring her food.
• A worker bee is observed flying away from its colony. Upon returning many other worker bees crowd around him while he moves in a distinct pattern.
• A lioness charges toward a large herd of galloping zebra, but then stops and runs away in the opposite direction.
• A certain species of short-horned grasshoppers changes color, band together, and fly over several square kilometers over a period of a few weeks.</td></tr>
<tr><td colspan="4" align="center">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4" align="center">Task Demands</td></tr>
<tr><td colspan="4">1. Based on the provided data, identify, describe, or construct a claim regarding how specific group behavior(s) can increase an individual's or species' chances of surviving and reproducing.</td></tr>
</table>

2.	Sort inferences about the effect of specific group behaviors on an individual's and species' chances to survive and reproduce into those that are supported by the data, contradicted by the data, outliers in the data, or neither, or some similar classification.
3.	Identify patterns of information/evidence in the data that support correlative/causative inferences about the effect of specific group behaviors on an individual's and species' chances to survive and reproduce.*
4.	Construct an argument using scientific reasoning, drawing on credible evidence to explain the effect of specific group behaviors on an individual's and species' chances to survive and reproduce.
5.	Identify additional evidence that would help clarify, support, or contradict a claim or causal argument regarding the effect of specific group behaviors on an individual's and species' chances to survive and reproduce.
6.	Identify, summarize, or organize given data or other information to support or refute a claim regarding the effect of specific group behaviors on an individual's and species' chances to survive and reproduce.**

*denotes those task demands which are deemed appropriate for use in stand-alone item development
**TD6 – summarize is the emphasis here. Avoid identify and organize.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS3-1
Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.</td></tr>
<tr><td>Dimensions</td><td>Asking Questions and Defining Problems
• Ask questions that arise from examining models or a theory to clarify relationships.</td><td>LS1.A: Structure and Function
• All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. (secondary)

LS3.A: Inheritance of Traits
• Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species’ characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements:
• At this level, the study of inheritance is restricted to Mendelian genetics, including dominance, codominance, incomplete dominance, and sex-linked traits.
• Focus is on expression of traits on the organism level and should not be restricted to protein production.

Content Limits:
• Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.
• Assessment does not include mutations or species-level genetic variation including Hardy-Weinberg equilibrium.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Genome, zygote, fertilization, dominant, recessive, codominance, incomplete dominance, sex-linked, allele, sequencing, pedigree, parent generation, F1, F2, haploid, diploid, replication.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Epigenetics, interphase, prophase, metaphase, anaphase, telophase, cytokinesis, epistasis.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS3-1:
• DNA sequencing shows that all people have the gene for lactase production, but only about 30% of adults can digest milk.
• Polydactyl tabby cat Jake holds the world record for most toes, with seven toes on each paw.
• E. coli bacteria are healthful in mammalian intestines but makes mammals sick when ingested.
• E. coli bacteria are used to produce human insulin.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Identify or construct an empirically testable question based on the phenomenon that could lead to design of an experiment or model to define the relationships between the role of DNA and/or chromosomes in the inheritance of traits.*
2. Assemble or complete, from a collection of potential model components, an illustration, or pedigree that is capable of representing the role of genetic material in coding the instructions for inheritance.*
3. Construct a question that arises from examining a model or theory to clarify the connections between DNA/chromosomes and inheritance of traits.*
4. Make predictions about the pattern of inheritance based on a model derived from the empirically testable question. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
5. Assemble or complete a flow chart describing the cause and effect relationships between genetic material and the characteristic traits passed from parents to offspring.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS3-2
Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Make and defend a claim based on evidence about the natural world that reflects scientific knowledge and student-generated knowledge.</td><td>LS3.B: Variation of Traits
• In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited.
• Environmental factors also affect expression of traits, and, hence, they affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation, and to make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on using data to support arguments for the way variation occurs.
• Inheritable traits should be traits that can be passed down through more than one generation.
• Inheritable traits for this PE do not include dominant/recessive traits.
• Examples of evidence for new genetic combinations and viable errors can include:
    o karyotype comparison between parents and children;
    o DNA sequence comparison.

Content Limits
• Assessment does not include assessing meiosis or the biochemical mechanism of specific steps in the process.
• <u>Students do not need to know</u>: bioinformatics, specific genetic disorders.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Amino acid, DNA, enzyme, protein synthesis, chromosome, egg, egg cell, sperm, sperm cell, dominant trait, recessive trait, recombination, sex cell, sex chromosome, sex-linked trait, meiosis, mutation, advantageous, expression, base pairs, genome, UV radiation, triplet codon, insertion, deletion, frameshift, substitution, somatic, epigenetic.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Polyploidy, single nucleotide polymorphisms (SNPs), conjugation, DNA polymerase, mutagenic, chromosomal translocation, missense, nonsense, nongenic region, tautomerism, depurination, deamination, slipped-strand mispairing, Sheik disorder, prion, epidemiology.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS3-2:
• Due to pesticide residue, frogs have extra, non-functioning, limbs.
• Most chickens have feathers that lay flat against their bodies. In one family of chickens, 50% of offspring have feathers that curl away from their bodies.
• A single gene mutation accounts for the blue color of irises in over 99.5% of people with blue eyes.</td></tr>
</table>

	• One sunflower growing in a field has a wide, flat stem and an unusual number of leaves. The next year, several sunflowers in the field share these traits.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Based on the provided data, make or construct a claim regarding inheritable genetic variations that may result from: 1) new genetic combinations through meiosis, 2) viable errors occurring during replication, and/or 3) mutations caused by environmental factors. This *does not* include selecting a claim from a list.
2. Sort inferences about inheritable genetic variation into those that are supported by the data, contradicted by the data, outliers in the data, or none of these—or some similar classification.
3. Identify patterns of information/evidence in the data that support correlative/causative inferences about inheritable genetic variation.
4. Construct an argument using scientific reasoning that draws on credible evidence to explain how inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. (Hand scored CR)
5. Identify additional evidence that would help clarify, support, or contradict a claim or causal argument.
6. Identify, describe, and/or construct alternate explanations or claims, and cite the data needed to distinguish among them.
7. Predict outcomes of genetic variations, given the cause-and-effect relationships of inheritance.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS3-3
Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.</td><td>LS3.B Variation of Traits
• Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.</td><td>Scale, Proportion and Quantity
• Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.
• Sensitivity and precaution should be used around the use of both lethal recessive and dominant human traits (i.e., Huntington's, achondroplasia, Tay-Sachs, cystic fibrosis).

Content Limits
• Assessment is limited to basic statistical and graphical analysis.
• Assessment does not include Hardy-Weinberg calculations ($p^2 + 2pq + q^2 = 1$ or $p + q = 1$).
• <u>Students do not need to know:</u> pleiotropy, meiosis, specific names of genetic disorders.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Gene, allele, dominant, recessive, homozygous, heterozygous, phenotype, genotype, P generation, F_1 generation, F_2 generation, complete dominance, incomplete dominance, codominance, pedigree, carrier, fertilization, sex linked traits, gamete, Mendelian genetics, zygote, haploid, diploid, epistasis.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Test-cross, monohybrid, dihybrid, law of independent assortment, law of segregation, pleiotropy, norm of reaction, multifactorial, Barr Body, genetic recombination, latent allele.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS3-3:
• O Positive is the most common blood type. Not all ethnic groups have the same mix of these blood types. Hispanic people, for example, have a relatively high number of O's, while Asian people have a relatively high number of B's.
• Hydrangea flowers of the same genetic variety range in color from blue-violet to pink, with the shade and intensity of color depending on the acidity and aluminum content of the soil.
• Most humans were born with five fingers on each hand, yet the polydactyl trait (having more than five fingers on each hand) is the dominant trait.
• When a red rose is crossed with a white rose, all pink roses are produced.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Describe data or patterns/relationships in given data that support (or refute) an explanation for the change in trait frequency or magnitude in a population, due to both genetic and environmental factors.*</td></tr>
<tr><td colspan="4">2. Make predictions about the trait frequency or distribution in a population due to the presence/absence or addition/removal of both genetic and environmental factors.*</td></tr>
</table>

3. Organize and/or arrange (e.g., using illustrations and/or labels) data, or summarize data to provide evidence for an explanation of the relationship between a trait's occurrence in a population and genetic and environmental factors.
4. Analyze, evaluate, estimate, calculate, and/or construct an equation for the statistical mean and/or the standard deviation, to describe the change in the distribution of a trait in a population over time, due to genetic and environmental factors.*
5. Identify statistical anomalies or outliers for a trait or a population that are outside the expected range (norm reaction), which may or may not be quickly removed due to genetic and environmental factors.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS4-1
Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating Information
• Communicate scientific information (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).</td><td>LS4.A: Evidence of Common Ancestry and Diversity
• Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.</td><td>Patterns
• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution.
• Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.

Content Limits
• <u>Students do not need to know</u>: specific genetic mutations, specific genetic disorders, specific proteins, Occam's razor (maximum parsimony), formation of orthologous and paralogous genes, molecular clock, Neutral theory.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Amino acids, cladogram, comparative anatomy, DNA sequencing, electrophoresis, embryology, evolution, fossil record, gene flow, genetic drift, mutation, natural selection, nucleotides, sedimentary layers, species, descent with modification, homologous structures, evolutionary tree, analogous structures.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Phylogenetic, phylogeny, phylogenetic tree, taxonomy, cladistics, vestigial structures, convergent evolution, analogous, endemic, phylocode, sister taxa, basal taxon, polytomy, homoplasy, molecular systematics, monophyletic, parphyletic, polyphyletic, maximum parsimony, orthologous genes, paralogous genes, horizontal gene transfer.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS4-1:
• Red pandas look a bit like bears and a bit like raccoons. Task Statement: Provide evidence about whether red pandas are better classified as raccoons or bears. Stimulus material might include pictures, DNA information, embryological information, and homologous structures.
• Hermit crabs live in shells, like oysters, but look like crabs. Provide evidence classifying hermit crabs either as mollusks (like oysters) or arachnids (like crabs).
• Crawfish look just like lobster, but smaller. Which came first, the lobster or the crawfish?
• Fossil records of an extinct hooved animal show a thickened knob of bone in its middle ear. This structure is also found in modern whales and helps them hear underwater.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

1. Analyze and interpret scientific evidence from multiple scientific/technical sources including text, diagrams, charts, symbols, mathematical representations that support common ancestry among organisms and/or biological evolution.*
2. Evaluate the validity/relevance/reliability of scientific evidence about biological evolution.
3. Identify relationships or patterns in scientific evidence at macroscopic and/or microscopic scales.*
4. Describe the specific evidence needed to support an explanation about how organisms share a common ancestor.
5. Synthesize an explanation that incorporates the scientific evidence from multiple sources.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS4-2
Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, and peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>LS4.B: Natural Selection
• Natural selection occurs only if there is both 1) variation in the genetic information between organisms in a population and 2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals.

LS4.C: Adaptation
• Evolution is a consequence of the interaction of four factors: 1) the potential for a species to increase in number, 2) the genetic variation of individuals in a species due to mutation and sexual reproduction, 3) competition for an environment’s limited supply of the resources that individuals need in order to survive and reproduce, and 4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on using evidence to explain the influence each of the four factors has on the number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species.
• Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.

Content Limits
• Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.
• Students do not need to know: Hardy-Weinberg equation.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Beneficial change, detrimental change, distribution, emergence, gene frequency, biotic, abiotic, advantageous, diverge, proliferation, bottleneck effect, island effect, geographic isolation, founder effect, recombination.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Hardy-Weinberg equilibrium, biotechnology, relative fitness, directional selection, disruptive selection, stabilizing selection, heterozygote advantage, frequency-dependent selection, prezygotic barriers, postzygotic barriers.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS4-2:
• Cane toads introduced to Australia in the 1930s have evolved to be bigger, more active, and have longer legs.</td></tr>
</table>

	• In the late 1990s, a resurgence of bedbug outbreaks began. Bedbugs are now much harder to kill with thick, waxy exoskeletons, faster metabolism, and mutations to block certain insecticides. • Skinks living in cooler regions give live birth, while those living in warm coastal areas lay eggs. • A butterfly parasite found on the Samoan Islands destroyed the male embryos of blue moon butterflies, decreasing the male population to only 1%. After a year, males had rebounded to 40% of the population.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Describe the cause-and-effect relationship between: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment, and change in species over time. This may include indicating directions of causality in a model or completing cause-and-effect chains.
2. Describe, identify, or select evidence supporting or contradicting a claim about the role of (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment in causing the phenomenon. The evidence may be evidence generated by the students in the simulation or selected from provided data.
3. Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes in environmental conditions on the population.
4. Use evidence to construct an explanation of the changes in species over time as a result of (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.***(SEP/DCI/CCC)**
5. Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses for the changes in species over time.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS4-3
Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.</td><td>LS4.B: Natural Selection
• Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation —that leads to differences in performance among individuals.
• The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.

LS4.C: Adaptation
• Natural selection leads to adaptation that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. The differential survival and reproduction of organisms in a population that have an advantageous heritable trait lead to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.
• Adaptation also means that the distribution of traits in a population can change when conditions change.</td><td>Patterns
• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.

Content Limits
• Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.
• <u>Students do not need to know</u>: sexual selection, kin selection, artificial selection, frequency-dependent selection.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Fitness, gene, allele, directional selection, diversifying (disruptional selection), stabilizing selection, standard deviation, vestigial structure.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Hemizygous, aneuploidy, intragenomic conflict, sexual dimorphism, balanced polymorphism, apostatic selection.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Example phenomena for HS-LS4-3:
• Green Treefrogs (Hyla versicolor) are abundant in the wetlands of Florida where no Gray Treefrogs (Hyla cinerea) are observed. In the wooded areas of New York, only Gray Treefrogs are observed.</td></tr>
</table>

	• In the Amazon rainforest, a kapok trees (*Ceiba pentandra*) measures 200 feet in height, approximately 30 feet above the rest of the canopy. • A school of mummichog fish (*Fundulus heteroclitus*) is found in the 6°C waters of the Chesapeake Bay. These fish are normally found in warmer climates, like the 21°C waters of Kings Bay, Georgia. • A population of the fish *Poecilia mexicana* lives in the murky hydrogen-sulfide (H2S)-rich waters in southern Mexico that would kill the same species of fish living in clear freshwaters only 10 km away.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Describe or identify patterns or relationships in given data that support (or refute) an explanation for the change in trait frequency or magnitude in a population due to natural selection/selection pressure(s).*
2. Make predictions about the trait frequency or distribution in a population due to the presence/absence or addition/removal of selection pressure(s) in the environment (including Hardy-Weinberg-based predictions about changes in allele/trait frequency/magnitude NOT based on calculations).*
3. Organize and/or arrange (e.g., using illustrations and/or labels) data, or summarize data to provide evidence for an explanation of the effect of selection on a population.
4. Analyze, evaluate, estimate, calculate, and/or construct an equation to describe the change in the distribution of a trait in a population over time due to selection pressure(s).
5. Identify statistical anomalies or outliers for a trait or a population that are outside the expected range (for example, Joe DiMaggio's hitting streak, tossing 10 consecutive heads on a fair coin, etc.) which may or may not be quickly removed due to selection pressure.
6. Use statistical analysis to calculate changes in traits in a population over time to provide evidence for an explanation of the relationship between a trait's occurrence and its prevalence in the population at different points in time.
7. Identify explanations for a change in a traits frequency and/or distribution in a population over time that can be supported by patterns or relationships in data.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

Performance Expectation	**HS-LS4-4** Construct an explanation based on evidence for how natural selection leads to adaptation of populations.		
Dimensions	**Constructing Explanations and Designing Solutions** • Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**LS4.C: Adaptation** • Natural selection leads to adaptation; that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. The differential survival and reproduction of organisms in a population that has an advantageous, heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
Clarifications and Content Limits	**Clarification Statement** • Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations. **Content Limits** • Assessment does not include the Hardy-Weinberg equation.		
Science Vocabulary Students Are Expected to Know	Beneficial change, detrimental change, distribution, emergence, gene frequency, gene, biotic, abiotic, advantageous, diverge, proliferation, sexual reproduction, bottleneck effect, island effect, geographic isolation, gene flow, genetic drift, founder effect.		
Science Vocabulary Students Are Not Expected to Know	Hardy Weinberg Equilibrium, biotechnology, relative fitness, directional selection, disruptive selection, stabilizing selection, heterozygote advantage, frequency-dependent selection, prezygotic barriers, postzygotic barriers.		
Phenomena			
Context/ Phenomena	Some example phenomena for HS-LS4-4: • Following a four-year drought in California, field mustard plants are found to flower earlier in the season. • A new antibiotic is discovered. Within ten years, many bacterial diseases that were previously treated by the antibiotic no longer respond to treatment (e.g., MRSA). • A small population of Italian wall lizards that feed mainly on insects is introduced to a neighboring island. After several decades, the lizards are found to have thrived and heavily populated the island, and their diet is now mostly vegetation. • Following climatic changes, the European Great Tit bird begins laying eggs earlier in the spring.		
This Performance Expectation and associated Evidence Statements support the following Task Demands.			
Task Demands			

1.	Organize or summarize the given data or evidence of population characteristics, environmental characteristics, and/or the relationships between them.
2.	Generate or construct graphs or tables of data to highlight patterns within the given data.
3.	Describe the cause and effect relationship between natural selection and adaptation using evidence. This may include assembling descriptions from illustrations or lists of options and distractors, or indicating directions of causality in a model or completing cause and effect chains.
4.	Describe, identify, or select evidence supporting or contradicting a claim about the role of adaptation in causing the phenomenon. The evidence may be generated by the students in a simulation.
5.	Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes in environmental conditions on the population.
6.	Use evidence to construct an explanation of the adaptation of a species through natural selection. Evidence can be described, identified, or selected/assembled from lists with distractors. Explanations can be written, assembled by manipulating the components of a flow chart or model, or assembled from lists of options that include distractors. Options and distractors should not be single words or short phrases; rather, they should be complete thoughts that, when correctly emplaced within a sentence or paragraph, work to provide evidence of a coherent train of thought.*
7.	Identify and justify additional pieces of evidence that would help distinguish among competing hypotheses.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

Performance Expectation	**HS-LS4-5** Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.		
Dimensions	**Engaging in Argument from Evidence** • Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.	**LS4.C: Adaptation** • Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes extinction—of some species. • Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
Clarifications and Content Limits	**Clarification Statements** • Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species. **Content Limits** • Students do not need to know: Hardy Weinberg Equation.		
Science Vocabulary Students Are Expected to Know	Beneficial change, detrimental change, distribution, emergence, gene frequency, biotic, abiotic, advantageous, diverge, mutation, proliferation, bottleneck effect, island effect, geographic isolation, founder effect, recombination, microevolution, gene flow, speciation, hybrid		
Science Vocabulary Students Are Not Expected to Know	Biotechnology, relative fitness, directional selection, disruptive selection, stabilizing selection, heterozygote advantage, frequency dependent selection, prezygotic barriers, postzygotic barriers, average heterozygosity, cline, sexual selection, sexual dimorphism, intrasexual selection, intersexual selection, neutral variation, balancing selection		
Phenomena			
Context/ Phenomena	Some example phenomena for HS-LS4-5: • PCB pollution in the Hudson River wiped out many fish species, but the Atlantic tomcod thrives there (results 1 and 3). • The population of Greater Prairie Chickens in Illinois decreased from millions of birds in the 1800s to fewer than 50 birds in 1993 (result 3). • In 1681 the dodo bird went extinct due to hunting and introduction of invasive species (result 3). • In 1988, the Orange-Spotted Filefish went extinct in response to warmer ocean temperatures (result 3).		
This Performance Expectation and associated Evidence Statements support the following Task Demands.			
Task Demands			
1. Based on the provided data, identify, describe, or construct a claim regarding the effect of changes to the environment on the (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.			

2.	Sort inferences about the effect of changes to the environment on (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species into those that are supported by the data, contradicted by the data, outliers in the data, or neither, or some similar classification.*
3.	Identify patterns of information/evidence in the data that support correlative/causative inferences about the effect of changes to the environment on the (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.*
4.	Construct an argument and/or explanation using scientific reasoning drawing on credible evidence to explain the effect of changes to the environment on the (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.
5.	Identify additional evidence that would help clarify, support, or contradict a claim or causal argument regarding the effect of changes to the environment on the (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.
6.	Identify, summarize, or organize given data or other information to support or refute a claim regarding the effect of changes to the environment on (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.*

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS4-6
Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Create or revise a simulation of a phenomenon, designed device, process, or system.</td><td>LS4.C: Adaptation
• Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species.

LS4.D: Biodiversity and Humans
• Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

ETS1.B: Developing Possible Solutions
• When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts (secondary).
• Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical, and in making a persuasive presentation to a client about how a given design will meet his or her needs (secondary).</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.
• The simulation should model the effect of human activity and provide quantitative information about the effect of solutions on threatened or endangered species or to genetic variation within a species.

Content Limits
• <u>Students do not need to know</u>: Calculus/advanced mathematics (e.g., exponential growth and decay)</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Anthropogenic, efficient, overexploitation, urbanization, acidification, deforestation, concentration, radiation, greenhouse gas, surface runoff, civilization, consumption, mass wasting, urban development, per-capita, degradation, pollutant, best practice, cost-benefit, extract, regulation</td></tr>
</table>

Science Vocabulary Students Are Not Expected to Know	Oligotrophic and eutrophic lakes/eutrophication, littoral zone, exponential population growth, logistic population growth, ecological footprint, ecosystem services, extinction vortex, minimum viable population, effective population size, critical load.
Phenomena	
Context/ Phenomena	Some example phenomena for HS-LS4-6: • The habitat of the Florida Panther is only 5% of its former range, causing the species to become endangered. • The café marron plant is critically endangered due to massive habitat destruction on the Island of Rodrigues in the Indian Ocean, as a result of deforestation for agricultural use. • The population of Atlantic Bluefin Tuna has declined by more than 80% since 1970 due to overfishing. • In the past 120 years, about eighty percent of suitable orangutan habitat in Indonesia has been lost from expansion of oil palm plantations. At the same time, the estimated number of orangutans on Borneo, an island in Indonesia, has declined from about 230,000 to about 54,000.
This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Use data to calculate or estimate the effect of a solution on mitigating the adverse impacts of human activity on biodiversity.	
2. Illustrate, graph, or identify features or data that can be used to determine how effective a solution is for mitigating the adverse impacts of human activity on biodiversity.	
3. Estimate or infer the properties or relationships that lead to mitigation of the adverse impacts of human activity on biodiversity, based on data.	
4. Compile the data needed for an inference about the impacts of human activity on biodiversity. This can include sorting out the relevant data from the given information.	
5. Using given information, select or identify the criteria against which the solution should be judged.	
6. Using a simulator, test a proposed solution and evaluate the outcomes; may include proposing modifications to the solution.*	

*In order to satisfy this PE, the student must use a simulator. Therefore, this task demand must always be used.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS1-1
Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun’s core to release energy that eventually reaches Earth in the form of radiation.</td></tr>
<tr><td>Dimensions</td><td>Developing and using models
• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>ESS1.A: The Universe and Its Stars
• The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.

PS3.D: Energy in Chemical Processes and Everyday Life
• Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (secondary)</td><td>Scale, Proportion, and Quantity
• The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun’s core to reach Earth.
• Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun’s radiation varies due to sudden solar flares (“space weather”), the 11-year sunspot cycle, and non-cyclic variations over centuries.

Content Limits
• Assessment does not include details of the atomic and sub-atomic processes involved with the sun’s nuclear fusion.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">sunspot cycle, solar maximum, solar minimum, sunspots, solar flares, UV radiation, IR radiation, convection, nuclear fusion, core, atmosphere, solar storm, luminosity</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">photosphere, chromosphere, corona, coronal mass ejections</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS1-1:
• The habitable zone in our solar system currently contains both Earth and Mars. In the future it will contain a different set of planets.
• The sun's current surface temperature is about 5,800 K. In 5 billion years, the sun's surface temperature will cool to 3,500 K.
• The sun is 40% brighter, 6% larger than 5% hotter than it was 5 billion years ago.
• The Earth’s atmosphere will contain more water vapor and the oceans will contain less water in a few billion years.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Organize and/or arrange (e.g., using illustrations and/or labels), summarize or make inferences about data to highlight trends, patterns, or correlations.</td></tr>
<tr><td colspan="4">2. Identify patterns or evidence in the data that supports inferences about the lifespan of the sun or the transfer of energy from the sun to the earth.</td></tr>
</table>

3.	Select or identify from a collection of potential model components, including distractors, the components needed for a model that illustrates the lifespan of the sun or the transfer of energy from the sun to the earth.
4.	Construct or complete a model capable of illustrating the lifespan of the sun or the transfer of energy from the sun to the earth.
5.	Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that are relevant to the lifespan of the sun or the transfer of energy from the sun to the earth.
6.	Identify missing components, relationships, or other limitations of the model.
7.	Make predictions about the effects of changes in the sun or in the transfer of energy from the sun to the earth. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS1-2
Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>ESS1.A: The Universe and Its Stars
• The study of stars’ light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
• The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.
• Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.

PS4.B: Electromagnetic Radiation
• Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. (secondary)</td><td>Energy and Matter
• Energy cannot be created or destroyed–only moved between one place and another place, between objects and/or fields, or between systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the astronomical evidence of the redshift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Recessional velocity, galaxy, star, galaxy cluster, spectrum, spectra, wavelength, frequency, Doppler Effect, redshift, blueshift, light years, big bang theory, helium, emission, absorption</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Cosmological redshift, Hubble Law, photometric redshift, spectroscopy</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example Phenomena for HS-ESS1-2:
• The farthest known galaxy has a greater recessional velocity than the farthest known quasar.
• The spectrum of NGC450 shows a greater abundance of elements heavier than helium than does the spectrum of NGC60</td></tr>
</table>

	• Two galaxy clusters observed in opposite parts of the sky both contain galaxies with about the same chemical composition: 75% hydrogen and 25% helium. • A galaxy in the constellation Cetus is moving away from us at a different speed than another galaxy in the adjacent constellation Pisces.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail organizing, interpreting and analyzing data, making calculations, and sorting relevant from irrelevant information or features.
2. Identify evidence that supports and/or does not support the Big Bang Theory.
3. Describe, select, or identify components of the Big Bang Theory supported by given evidence.
4. Use an explanation of the Big Bang Theory to predict how the universe will continue to change over time.
5. Construct an explanation based on evidence that explains how particular aspects of the Big Bang Theory are supported by empirical observations of the universe.
6. Identify and justify additional pieces of evidence that would help distinguish among competing hypotheses.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS1-3
Communicate scientific ideas about the way stars, over their life cycle, produce elements.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating Information
• Communicate scientific ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).</td><td>ESS1.A: The Universe and Its Stars
• The study of stars’ light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
• Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.</td><td>Energy and Matter
• In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.

Content Limits
• Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.
• Include basic/simplified nucleosynthesis reactions:
o Hydrogen fuses into helium
o Helium fuses into carbon
o Carbon fuses into oxygen
o Oxygen fuses into silicon
o Silicon fuses into iron
• Exclude complex nucleosynthesis reactions and details:
o CNO cycle
o Neutron-capture (r-process and s-process)
o Proton-capture: Rp-process
o Photo-disintegration: P-process
o Other details about radiation or particles – focus on conservation of nucleons</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">main sequence, nucleosynthesis, nuclear reactions, fission, fusion, nucleons, proton, neutron, , , gamma rays, neutrinos, red giant, blue giant, white dwarf, planetary nebular, supernova, supernova remnant, globular cluster, open , exothermic reactions, endothermic reactions, emissions spectrum, absorption spectrum, emission lines, absorption lines, H-R Diagram</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Neutron-capture, proton-capture, photo-disintegration, CNO cycle, radiogenesis</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomenon for HS-ESS1-3:
• Two larger stars, Spica and Pollux are eight times larger than the sun. However, Spica is 420 times brighter and 6 times more massive than Pollux.
• Procyon is a 1.5 solar mass star and is 8 times brighter than the sun. Aldebaran is a star of similar mass but Aldebaran is 425 times brighter than the sun.</td></tr>
</table>

	• The stars in a globular cluster (old low mass stars) are red and show few absorption lines in their spectra while the stars in an open cluster (young high mass stars) are blue and show many absorption lines in their spectra. • In the core of some stars, carbon can fuse into neon, sodium or magnesium.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Illustrate, model or make calculations involving the nucleosynthesis process in stars of different mass, different luminosity, different age or different evolutionary stage using graphs, diagrams, text and mathematical models.
2. Compare and contrast the nucleosynthesis processes of stars of different mass, different luminosity, different age or different evolutionary stage using graphs, diagrams, text and mathematical models.
3. Make predictions about nucleosynthesis processes given changes or differences in other stellar characteristics.
4. Identify and communicate evidence supporting an explanation regarding the relationship between stellar properties and age, in particular how those stellar properties change over time.
5. Synthesize an explanation regarding the relationship between stellar properties and age, in particular how those stellar properties change over time.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS1-4
Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematical and Computational Thinking
• Use mathematical or computational representations of phenomena to describe explanations.</td><td>ESS1.B: Earth and the Solar System
• Kepler’s laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.</td><td>Scale, Proportion, and Quantity
• Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets, moons, rings, asteroids, and comets.
• The term “satellite” can be used to describe both man-made and natural objects that orbit another object.

Content Limits
• Mathematical representations for the gravitational attraction of bodies and Kepler’s Laws of orbital motions should not deal with systems of more than two bodies, nor involve calculus.
• Comparing different orbiting bodies is acceptable as long as each system only contains two bodies (example: satellite 1 orbiting Earth compared to satellite 2 orbiting Earth).
• Students will be given the Law of Gravitation to make calculations but should know/apply Kepler’s laws conceptually. These laws are:
1. Orbits are elliptical;
2. Line connecting orbiting body and parent body sweeps out equal areas in equal time;
3. (Orbital period)^2 is proportional to (semi-major axis distance)^3.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Gravitation, orbit, revolution, rotation, period, semi-major axis, eccentricity, semi-minor axis, focus, foci, ellipse, gravitational constant, astronomical unit, satellite</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Aphelion, perihelion, angular momentum</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some sample phenomena for HS-ESS1-4:
• The International Space Station orbits Earth at an altitude of 250 miles with a speed of 5 miles per second while a global positioning system satellite orbits ten times as far and half as fast.
• China’s Tiangong space station’s orbital speed can no longer be controlled. It is expected to burn up in the atmosphere as it falls to the Earth.
• The shape of Comet Shoemaker-Levy 9’s orbit changed just before it collided with Jupiter in 1994.
• In 100 years, the moon will be about half a meter further from Earth and Earth’s rotation will be 2 miliseconds slower.</td></tr>
<tr><td colspan="4" align="center">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
</table>

Task Demands
1. Make simple calculations using given data to calculate or estimate the motion of orbiting objects (satellites).
2. Illustrate, graph, or identify relevant features or data that can be used to calculate, estimate or make inferences about the motion of satellites.
3. Calculate or estimate properties of motions for a satellite and the object it orbits based on data from one or more sources.
4. Select or construct relationships between a satellite and the object it orbits based on data from one or more sources.
5. Compile, from given information, the particular data needed for a particular inference about the motion of a satellite. This can include sorting out the relevant data from the given information.
6. Construct or identify an inference that can be made based on data from one or more sources.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS1-5
Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments.</td><td>ESS1.C: The History of Planet Earth
• Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old.

ESS2.B: Plate Tectonics and Large-Scale System Interactions
• Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth’s surface and provides a framework for understanding its geologic history. (secondary)

PS1.C: Nuclear Processes
• Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. (secondary)</td><td>Patterns
• Empirical evidence is needed to identify patterns.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks.
• Examples include evidence of the ages of oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust decreasing with distance away from a central ancient core of the continental plate (a result of past plate interactions).

Content Limits
• Students do not need to calculate radioactive decay rates.
• <u>Students do not need to know:</u> names of supercontinents, names of fault lines, names of tectonic plates</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Convergence, divergence, sedimentary, metamorphic, igneous, volcanic, crust, mantle, core, mid ocean ridge, trench</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Isotope, anticline, syntacline</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS1-5:
• Rocks near Bildudalur Iceland were formed about about 16 million years ago, rocks near Geysir Iceland were formed about 3.3 million years ago.
• The patterns of magnetic reversals on the youngest continental rock columns are the same as the pattern of magnetic reversals found at the center of the Mid-Atlantic ridge.
• Iceland gains about 1.8 centimeters of land surface per year.
• From 1996 to 2016, Mount St. Elias has gotten 0.08 meters taller.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
</table>

Task Demands
1. Based on the provided data or information, identify the explanation that could explain the age difference in continental and oceanic crust.
2. Identify and/or explain the claims, evidence, and reasoning supporting the explanation that tectonic plates have moved over time.
3. Identify and/or describe additional relevant evidence not provided that would support or clarify the explanation of the movement of tectonic plates and/or the ages of rocks.
4. Evaluate the strengths and weaknesses of a claim to explain the theory of plate tectonics and the ages of rocks.
5. Analyze and/or interpret evidence and its ability to support the explanation that plate tectonics or radioactive decay can determine the age of a rock.
6. Provide and/or evaluate reasoning to support the explanation that volcanoes, mountains and earthquakes are formed/caused as a result of plate tectonics

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS1-6
Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.</td><td>ESS1.C: The History of Planet Earth
• Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.

PS1.C: Nuclear Processes
• Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. (secondary)</td><td>Stability and Change
• Much of science deals with constructing explanations of how things change and how they remain stable.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago.
• Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Plate tectonics, radiometric dating, isotope, continental crust, oceanic crust, lithosphere, asthenosphere, cycle, bedrock, ocean trench, sedimentation, convection current, ancient core, inner core, mantle, nuclear, ocean ridge, sea-floor spreading</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Nebular hypothesis, planetesimals, solar nebula, bolide impacts,</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some sample phenomena for HS-ESS1-6:
• A thin section of a rock from western Australia is examined under a microscope and elongate crystals are observed.
• A rock from Earth and a rock from Mars are the same age.
• When astronauts returned to Earth with rocks from the moon, they were all very old. A rock found in the Great Lakes Region of North America is very old, but rock found in Iceland are all relatively young. Meteor Crater is a large depression, with a depth of 170m, in an otherwise flat area of Arizona.</td></tr>
<tr><td colspan="4" align="center">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4" align="center">Task Demands</td></tr>
<tr><td colspan="4">1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.</td></tr>
<tr><td colspan="4">2. Express or complete a causal chain explaining Earth's formation and/or early history. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.*</td></tr>
</table>

3.	Identify evidence supporting the inference of causation that is expressed in a causal chain.
4.	Describe, identify, and/or select information needed to support an explanation about the formation of Earth and its early history.
5.	Construct an explanation based on evidence and scientific reasoning that explains the formation of Earth and its early history. *****

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS2-1
Develop a model to illustrate how Earth’s internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>ESS2.A. Earth Materials and Systems
• Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

ESS2.B. Plate Tectonics and Large-Scale System Interactions
• Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth’s surface and provides a framework for understanding its geologic history.
• Plate movements are responsible for most of continental and ocean-floor features and for the distribution of most rocks and minerals within Earth’s crust.</td><td>Stability and Change
• Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).

Content Limits
• <u>Students do not need to know: </u>the details of the formation of specific geographic features of Earth’s surface.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Tectonic uplift, seismic waves, feedback effect, irreversible, Earth’s magnetic field, electromagnetic radiation, inner core, outer core, mantle, continental crust, oceanic crust, sea-floor spreading, isotope, thermal convection, radioactive decay, rock composition, continental boundary, ocean trench, recrystallization, nuclear, geochemical reaction, mass wasting</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Geomorphology, anticline, syncline, monocline</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some sample phenomena for HS-ESS2-1:
• A limestone cliff that contains Cambrian-aged fossils extends several hundred feet above the surface of the ocean. A large section of the cliff has collapsed.
• An oceanic trench 10,000 is meters below sea level. Inland, 200km away, a chain of active volcanoes is present.
• 1.8 billion year old rocks in the Black Hills of South Dakota are capped by 10,000 year old gravel terraces.
• A photograph from March shows large Precambrian-aged pink granite boulder at the top of a 100 m tall hill. A photograph in April shows the same boulder sitting in a pile of soil and sediment in the valley below the hill.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

1.	Select or identify from a collection of potential model components, including distractors, the components that are relevant for explaining the phenomenon. Components might include different rock types, rates of uplift and erosion, surface environments on Earth where these processes occur and where different rock types exist, and layers within Earth where these processes occur. Sources of energy (radiation, convection) that drive the cycling (but *not* the creation of) matter should also be included as components.*
2.	Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon of Earth's internal and surface processes.
3.	Make predictions about the effects of changes in the magnitude and/or rate of Earth's internal and surface properties. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
4.	Given models or diagrams of land features, internal and surface processes, identify factors that affect constructive and destructive forces, feedback effects and how they vary in different scenarios OR identify the constructive and destructive mechanisms that operate at different spatial and temporal time scales and how this causes changes in the appearance of continental and ocean-floor features.
5.	Identify missing components, relationships, or other limitations of the model of how Earth's internal and surface processes form continental and ocean-floor features.
6.	Describe, identify, or select the relationships among components of a model that describe the formation of continental and ocean-floor features with respect to spatial and temporal variability in internal and external surface processes or explains how changes in these processes affect the formation of continental and ocean-floor features.*
7.	Express or complete a causal chain explaining how changes in the flow of energy (interval vs. surface processes) affect the formation of continental and ocean-floor features. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS2-2
Analyze geoscience data to make the claim that one change to Earth’s surface can create feedbacks that cause changes to Earth’s systems.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze data using tools, technologies and/or models (e.g. computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design.</td><td>ESS2.A: Earth Materials and Systems
• Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

ESS2.D: Weather and Climate
• The foundation for the Earth’s global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage and redistribution among the atmosphere, ocean, and land systems, and this energy’s re-radiation into space.</td><td>Stability and Change
• Feedback (negative or positive) can stabilize or destabilize a system.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples should include climate feedbacks, such as:
o An increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth’s surface, increasing surface temperatures and further reducing the amount of ice.
o Loss of ground vegetation causes an increase in water runoff and soil erosion
o Damned rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion
o Loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.

Content Limits
• <u>Students do not need to know:</u>
o Specifically which gases are greenhouse gases.
o Composition of the atmosphere</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Ocean circulation, biosphere, feedback effect, atmospheric circulation, convection cycle, greenhouse gas, geoscience, sea level, mean surface temperature, methane</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Electromagnetic radiation, probabilistic, irreversible, geoengineering, ozone, pollutant, acidification</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS2-2:
• Farming causes the loss of forest in the Amazon. This leads to an increase in erosion and water runoff, which leads to more forest loss.
• Loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.
• As the Permafrost in the Artic melts, methane is released into the atmosphere. Methane, a greenhouse gas, traps heat causing the Earth to heat up, leading to more Permafrost melting.
• Increased CO2 in the atmosphere warms the oceans. Warmer oceans take up less CO2 than cooler oceans, further increasing atmospheric temperature.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations in how changes to Earth’s surface can create feedbacks that affect Earth’s systems.
2. Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations in how changes to Earth’s surface can create feedbacks that affect Earth’s systems. This may include sorting out distractors.
3. Use relationships identified in the data to predict how changing the Earth’s surfaces affects the feedback loop.
4. Identify patterns or evidence in the data that supports inferences about how the altering of Earth’s surface will affect the Earth in the long term.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS2-3
Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.</td></tr>
<tr><td>Dimensions</td><td>Develop and Using Models
• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>ESS2.A: Earth Materials and Systems
• Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior.

ESS2.B: Plate Tectonics and Large-Scale System Interactions
• The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection.

PS4.A: Wave Properties
• Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet (secondary)</td><td>Energy and Matter
• Energy drives the cycling of matter within and between systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics.
• Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Convection, radioactive, inner core, outer core, isotope, mantle, seismic wave, Geochemical reaction, geoscience, molten rock, Earth's elements, Earth's internal energy sources, geochemical cycle, tectonic uplift</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Geoneutrino, primodial heat</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS2-3:
• The temperature of the water in a hot spring in Iceland is around 100°F. The average air temperature in Iceland is about 52°F.
• The average heat flow from the Earth's interior is 80 mWm^{-2}. The heat flow of a volcano on Hawaii is ~400 mWm^{-2}.</td></tr>
</table>

	• The total heat transfer from the Earth to space is 44 terawatts. Radioactive decay of unstable isotopes contributes 20 terawatts from Earth's interior. (KamLAND Collaboration, 2011). • In the central valley of California, the temperature at 5 meters below the ground is 2°C warmer than the temperature at the surface. In northern Oregon near Mt. Hood, the temperature 5 meters underground is 10°C warmer than the temperature at the surface.
This Performance Expectation and associated Evidence Statements support the following Task Demands.	
Task Demands	
1. Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include the structure of the Earth, the cycling of matter and/or energy, or instruments used to measure seismic waves.	
2. Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing the structure and the flow of matter/energy from the Earth's interior. This does not include labeling an existing diagram.	
3. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.	
4. Make predictions about the effects of changes in the cycling of matter and energy. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.	
5. Given models or diagrams of the earth's interior, identify the chemical and physical properties of the Earth's structure that cause the cycling of matter.	
6. Identify missing components, relationships, or other limitations of the model.	
7. Describe, select, or identify the relationships among components of a model that describe the cycling of matter within Earth's interior.	

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS2-4
Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Use a model to provide mechanistic accounts of phenomena.</td><td>ESS1.B: Earth and the Solar System
• Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on Earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (secondary)

ESS2.A: Earth Materials and Systems
• The geologic record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output of Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of timescales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

ESS2.D: Weather and Climate
• The foundation for Earth's global climate system is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems and this energy's re-radiation into space.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of the causes of climate change differ by time scale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.

Content Limits
• Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.
• <u>Students do not need to know:</u> chemical mechanisms of fossil fuel combustion or ozone depletion</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Interdependence, solar radiation, solar flare, biosphere, atmospheric circulation, ocean circulation, climatic patternsea level, glacier, atmospheric composition, hydrosphere, greenhouse gas, fossil fuel, combustion</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Acidification, cryosphere</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
</table>

<table>
<tr><td>Context/
Phenomena</td><td>Some example phenomena for HS-ESS2-4:
• Temperatures were warmer in 1990 than in the 5 previous years. In 1992 and 1993, the global temperatures were 1°F cooler than in 1991. (volcanic eruption of Mount Pinatubo)
• 11,000 years ago large portions of the northern United States contained glaciers. Today, very little of this area contains glaciers. (changes to Earth’s orbit)
• Earth experiences 4 distinct seasons. Venus does not experience distinct seasons. (tilt of planet’s axis)
• 25,000 years ago, the level of carbon dioxide in the atmosphere was around 180 parts per million (ppm). Today, carbon dioxide levels exceed 400 ppm. (atmospheric composition)</td></tr>
<tr><td colspan="2">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="2">Task Demands</td></tr>
<tr><td colspan="2">1. Select or identify from a collection of potential model components, including distractors, the components that are relevant for explaining the phenomenon. Components might include factors that affect the input, storage, redistribution, and output of energy in Earth’s systems.</td></tr>
<tr><td colspan="2">2. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon of the flow of energy in Earth’s systems.</td></tr>
<tr><td colspan="2">3. Make predictions about the effects of changes in energy flow on Earth’s climate.</td></tr>
<tr><td colspan="2">4. Given models or diagrams of energy flow in Earth’s systems, identify factors that affect energy input, output, storage, and redistribution and how they change in different scenarios OR identify the changes in energy flow that cause changes in Earth’s climate.</td></tr>
<tr><td colspan="2">5. Identify missing components, relationships, or other limitations of the model of energy flow in Earth’s systems.</td></tr>
<tr><td colspan="2">6. Describe, identify, or select the relationships among components of a model that describe changes in the flow of energy in Earth’s systems or explains how changes in energy flow affect climate.</td></tr>
<tr><td colspan="2">7. Express or complete a causal chain explaining how changes in the flow of energy in Earth’s systems affects climate. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.</td></tr>
</table>

Performance Expectation	**HS-ESS2-5** Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.		
Dimensions	**Planning and Carrying Out Investigations** • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., the number of trials, cost, risk, time), and refine the design accordingly.	**ESS2.C: The Roles of Water in Earth's Surface Processes** • The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.	**Structure and Function** • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.
Clarifications and Content Limits	**Clarification Statements** • Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide evidence for the connections between the hydrologic cycle and system interactions commonly known as the rock cycle. • Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, and frost wedging by the expansion of water as it freezes. • Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids). **Content Limits** • The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting points of rocks.		
Science Vocabulary Students are Expected to Know	Viscosity, melting point, freezing point, absorption, dissolve, hydrologic cycle, rock cycle, stream transportation, stream deposition, stream table, erosion, soil moisture content, frost wedging, chemical weathering, solubility, mechanical erosion, heat capacity, density, molecular structure, sediment, cohesion, polarity.		
Science Vocabulary Students are Not Expected to Know			
Phenomena			
Context/ Phenomena	Some example phenomena for HS-ESS2-5: • In a cave in Guam, sections of stalactites that formed during seasons of high rainfall contain a lower ratio of the isotopes oxygen-18 to oxygen-16 than sections of the stalactites that formed during seasons of low rainfall.		

	• Wookey Hole Caves have about 4,000 meters of cave system in a rock formation. • The Colorado River runs through the rock formation known as the Grand Canyon.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Identify from a list, including distractors, the materials/tools needed for an investigation of the properties of water and its effects on Earth's materials and surface processes.
2. Identify the outcome data that should be collected in an investigation of the properties of water and its effects on Earth's materials and surface processes.
3. Evaluate the sufficiency and limitations of data collected to explain the effects of water on Earth's materials and surface processes.
4. Make and/or record observations about the chemical and/or physical properties of liquid water and its effects on Earth's materials.
5. Interpret and/or communicate the data from an investigation of the effect of water on Earth's materials and surface processes.
6. Explain or describe the causal processes that lead to the observed effects of water.
7. Select, describe, or illustrate a prediction made by applying the findings from an investigation of the effects of water on Earth's materials and surface processes.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS2-6
Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>ESS2.D Weather and Climate
• Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.
• Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.</td><td>Energy and Matter
• The total amount of energy and matter in closed systems is conserved.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.

Content Limits
• <u>Students do not need to know:</u> How to calculate the residence time by dividing the reservoir size by the flow rate, either in or out; how to calculate the biomass in a given ecosystem.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Concentration, rate of transfer/flow, pathway, hydrosphere, geosphere, biosphere, reservoir, sink, basin, pool, accumulate, biomass, equilibrium, chemosynthesis, byproduct, element, hydrocarbon, organic, inorganic, biotic, abiotic, diffusion, decompose, decay, microbe, fungi, bacteria, sediments, sequestered</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">assimilation, residence time, facies, orogenic, strata, outgassing, LeChatelier’s Principle</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS2-6:
• Data indicates that higher levels of atmospheric carbon dioxide increase both carbon's input and release from the soil.
• Even though trees take up carbon dioxide from the atmosphere, scientists find little carbon accumulation in the soil of a North Carolina forest.
• Human activity releases more than 30 billion tons of carbon dioxide into the atmosphere per year. However, scientists estimate that Earth's soil releases roughly nine times more carbon dioxide into the atmosphere than all human activities combined.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Select or identify from a collection of potential model components, mathematical variables, and/or mathematical operators, including distractors, the components, variables, and/or operators needed to mathematically and/or quantitatively model the phenomenon. Components and mathematical variables might include/represent organisms, spheres, molecules and/or elements, chemical, physical, and/or biological processes, and reservoirs. Operators might include symbols for addition, subtraction, multiplication, division, etc.</td></tr>
<tr><td colspan="4">2. Assemble or complete, from a collection of potential model components, mathematical variables, and/or mathematical operators, an illustration or flow chart that is capable of mathematically and/or quantitatively</td></tr>
</table>

	representing how matter and energy are continuously transferred within and between organisms and their physical environment. This does not include labeling an existing diagram.
3.	Describe, select, or identify the mathematical and/or quantitative relationships among components of a model and/or mathematical variables that describe how matter and energy are continuously transferred within and between organisms and their physical environment.
4.	Manipulate the components of a mathematical and/or quantitative model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.
5.	Make predictions about the effects of changes in the rate at which materials or elements move from one reservoir or sphere to another. Predictions can be made by manipulating model components, mathematical variables, and/or mathematical formulas, completing illustrations, selecting from lists with distractors, or performing calculations given sufficient information to do so.
6.	Given mathematical and/or quantitative models or diagrams of how matter and energy are continuously transferred within and between organisms and their physical environment, identify the pathways of matter and/or energy transfer within an environment and how they change in each scenario OR identify the properties of the environment that cause changes in the transfer of matter and/or energy within that environment.
7.	Identify missing components, mathematical variables, mathematical and/or quantitative relationships, or other limitations of the mathematic and/or quantitative model.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS2-7
Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Construct an oral and written argument or counter-arguments based on data and evidence.</td><td>ESS2.D: Weather and Climate
• Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.

ESS2.E: Biogeology
• The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.</td><td>Stability and Change
• Much of science deals with constructing explanations of how things change and how they remain stable.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and the Earth's systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface.
• Examples include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; and how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.

Content Limits
• Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Plate tectonics, rock formation, geologic evidence, ocean basin, radioactive, rock strata, time scale, continental boundary, ocean trench, sedimentation, continental shelf, crustal deformation, crustal plate movement, fracture zone, convection, atmospheric composition, groundwater, igneous rock, metamorphic rock, sedimentary rock, water cycle, landslide, deposition, greenhouse gas, mass wasting, molten rock, surface runoff</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Ecosystem services, Anthropocene, eutrophication, ecohydrology, geomorphology, heterogeneity</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS2-7:
• Eospermatopteris fossils (first trees) begin to appear in rocks dated 390 million years. Fossils of Tiktaalik (four legged fish), one of the earliest land animals, are found in the rock layers above Esopermatopteris.
• The appearance of cyanobacteria is recorded in fossils that formed roughly 3.5 billion years ago. Superior Type banded iron formed roughly 1.8 to 2.7 billion years ago. It is characterized by alternating red and gray layers of iron rich minerals and silica rich minerals.
• The Rhynie Chert beds in Aberdeenshire Scotland contain detailed fossils of early plants. Bryophyte fossils from about 500 million years ago, show small simple structured plants. Cooksonia pertoni fossils from about 430 million years ago show plants that were larger, spore bearing, and contained tissues that move water through the plant (vascular).</td></tr>
</table>

	• In 2016 two-thirds of the Northern portion of the Great Barrier Reef experienced severe bleaching. The Great Barrier Reef prior to this event, was made up of corals with a variety of bright colors that attracted a variety of marine life. In 2016, the coral turned completely white and few fish inhabit the area where bleaching has occurred.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
2. Express or complete a causal chain explaining how Earth's systems coevolved simultaneously with life on Earth. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.
3. Identify and/or describe additional relevant evidence not provided that would support or clarify the explanation of the simultaneous coevolution of Earth's systems and life on Earth. This may entail sorting relevant from irrelevant information or features.
4. Construct or identify from a collection, including distractors, an explanation based on evidence that explains how Earth's systems coevolved simultaneously with life on Earth.*
5. Describe, identify, and/or select information and/or evidence needed to support an explanation. This may entail sorting relevant from irrelevant information or features.
6. Identify patterns or evidence in the data that support conclusions about the relationship between the evolution of life on Earth and Earth's systems.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS3-1
Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>ESS3.A: Natural Resources
• Resource availability has guided the development of human society.

ESS3.B: Natural Hazards
• Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels.
• Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts).
• Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.

Content Limits
• <u>Students do not need to know:</u> distribution of specific resources</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Renewable, non-renewable, mitigation, economic cost.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Biome</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS3-1:
• In 2001, 85% of Australians lived within 50 km of the ocean.
• There are large solar power plants in the southern California desert. California solar power had a capacity of 18,296 MW in 2016. In the same year, New York State had a capacity of 927 MW.
• As many as 1.5 million inhabitants of Dhaka, Bangladesh, have moved there from villages near the Bay of Bengal.
• After the eruption of Mt. Vesuvius in 79 AD, the city of Pompeii was completely buried in volcanic ash. The city was never reoccupied and was lost for more than 1,500 years.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
</table>

Task Demands
1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.
2. Express or complete a causal chain explaining how resource availability/natural hazards/climate change drive changes in human society/population/migration. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.*
3. Identify evidence supporting the inference of causation that is expressed in a causal chain.
4. Use an explanation to predict the change in human /activity given a change in resource availability/natural hazards/climate.
5. Describe, identify, and/or select information and/or evidence needed to support an explanation.
6. Construct an explanation based on evidence that explains that the availability of natural resources/occurrence of natural hazards/changes in climate have influenced human activity.*

*denotes those task demands which are deemed appropriate for use in stand-alone item development.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS3-2
Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical, considerations).</td><td>ESS3.A: Natural Resources
• All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.

ETS1.B: Developing Possible Solutions
• When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts (secondary)</td><td></td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements:
• Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not.
• Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Renewable, non-renewable, mitigation, economic cost, irreversible, reversible, exponential, logarithmic, basin, sustainability, recycle, reuse, species, societal, wetland, groundwater, metal, consumption, per-capita, stabilize, fossil fuel, mining, conservation, extract, agriculture, timber, fertile land, solar radiation, biotic, abiotic, depletion, extinction, economics, manufacturing, technology,</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Trigonometric, derivative, feedback, regulation, dynamic, aquifer, hydrothermal, geopolitical, oil shale, tar sand, urban planning, waste management, fragmentation</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS3-2:
• There is a tower in the middle of North Dakota with flames shooting out the top of it.
• In Pennsylvania, a match is struck next to a running water faucet and a large flame appears.
• On the Yangtze River in China, blades of an underwater turbine turn and generate electricity.
• In the desert of Oman, a farmer uses seawater to irrigate crops.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail organizing, interpreting and analyzing data, making calculations, and sorting relevant from irrelevant information or features.</td></tr>
<tr><td colspan="4">2. Identify evidence that supports and/or does not support the success of competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios, societal needs for that resource, and associated environmental risks and benefits.</td></tr>
<tr><td colspan="4">3. Describe, select, or identify components of competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios supported by given evidence.</td></tr>
</table>

4.	Evaluate the strengths of competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios, societal needs for that resources, and associated environmental risks and benefits.
5.	Use an explanation of the design solutions for developing, managing, and utilizing energy and mineral resources to evaluate which design solution has the most preferred cost-benefit ratio.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS3-3
Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Create a computational model or simulation of a phenomenon, designed device, process, or system.</td><td>ESS3.C: Human Impacts of Earth Systems
• The sustainability of human societies and the biodiversity that supports them require responsible management of natural resources.</td><td>Stability and Change
• Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
Examples of factors that affect the management of natural resources include the costs of resource extraction and waste management, per-capita consumption, and development of new technologies.
Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.
Content Limits
Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Biosphere, geosphere, hydrosphere, renewable, non-renewable, mitigation, economic cost, irreversible, reversible, exponential, logarithmic, basin, ecological, biome, recycle, reuse, mineral, societal, wetland, consumption, per-capita, mining, conservation, extract, agriculture, timber, fertile land, solar radiation, biotic, abiotic, depletion, extinction, manufacturing, technology</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Trigonometric, derivative, feedback, regulation, dynamic, aquifer, hydrothermal, geopolitical, oil shale, tar sand, urban planning, waste management, fragmentation</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS3-3:
The number of birds and other wildlife in an area decreases by 30% after a shopping mall is built in northern California.
Two 1,330 square-foot homes are side by side in northern California. One has six solar panels on the roof, and the other does not. During one month in June, the one with solar panels produces less carbon dioxide than the other house by174 kilograms.
Beetles are present throughout a forest. Chemicals are sprayed at intervals needed to control the beetles on one acre. Fifty years later, this acre is the only part of the forest that has oak trees.
Three species of fish, the Colorado squawfish, the roundtail chub, and the bonytail chub became extinct in the years immediately following construction of the Glen Canyon Dam in Colorado.</td></tr>
<tr><td colspan="4" align="center">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4" align="center">Task Demands</td></tr>
<tr><td colspan="4">1. Use data to calculate or estimate the effect of an action or solution on natural resources, the sustainability of human populations, and/or biodiversity.</td></tr>
<tr><td colspan="4">2. Illustrate, graph, or identify features or data that can be used to determine the effects of an action or solution on natural resources, the sustainability of human populations, and/or biodiversity.</td></tr>
</table>

3.	Estimate or infer the effects of an action or solution that affects natural resources, the sustainability of human populations, and/or biodiversity.
4.	Compile the data needed for an inference about the impacts of an action or solution on natural resources, the sustainability of human populations, and/or biodiversity. This can include sorting out the relevant data from the given information (or choosing relevant inputs for a simulation).
5.	Using given information, select or identify the criteria against which the solution should be judged.
6.	Using a simulator, test a proposed action or solution and evaluate the outcomes; may include proposing modifications to the action or solution.*****
7.	Evaluate and/or critique models, simulations, or predictions in terms of identifiable limitations and whether or not they yield realistic results.

*In order to satisfy this PE, the student must use a simulator. Therefore, this task demand must always be used.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS3-4
Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.</td><td>ESS3.C: Human Impacts on Earth Systems
• Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.

ETS1.B Developing Possible Solutions
• When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts (secondary)</td><td>Stability and Change
• Feedback (negative or positive) can stabilize or destabilize a system.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining).
• Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Renewable, non-renewable, mitigation, economic cost, irreversible, reversible, exponential, logarithmic, basin, recycle, reuse, societal, wetland, metal, consumption, per-capita, biodiversity, stabilize, mining, conservation, extract, agriculture, timber, fertile land, solar radiation, biotic, abiotic, depletion, extinction, economics, manufacturing, technology</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Trigonometric, derivative, feedback, regulation, dynamic, aquifer, hydrothermal, geopolitical, oil shale, tar sand, urban planning, waste management, fragmentation</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS3-4:
• Recycling and composting almost 87 million tons of municipal solid waste saved more than 1.1 quadrillion Btu of energy; roughly equivalent to the same amount of energy consumed by 10 million U.S. households in a year.
• Mixed Paper recycling saves the equivalent of 165 gallons of gasoline.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail organizing, interpreting and analyzing data, making calculations, and sorting relevant from irrelevant information or features.</td></tr>
<tr><td colspan="4">2. Identify evidence that supports and/or does not support the success of the technological solution that reduced impacts of human activities on natural systems.</td></tr>
<tr><td colspan="4">3. Describe, select, or identify components of the impacts of human activities on natural systems supported by given evidence.</td></tr>
</table>

4. Use an explanation of the impacts of human activities on natural systems to explain the technological solution.
5. Identify or select the information needed to support an explanation of the impacts of human activities on natural systems.
6. Using given information about the effects of human activities on natural systems, select or identify criteria against which the solution should be judged.
7. Using given information about the effects of human activities on natural systems, select or identify constraints that the solution must meet.
8. Evaluate the criteria and constraints, along with trade-offs, for a proposed or given solution to resolve or improve the impact of human activities on natural systems.
9. Using given data, propose a potential solution to resolve or improve the impact of human activities on natural systems.
10. Using a simulator, test a proposed solution to resolve or improve the impact of human activities on natural systems, biodiversity and evaluate the outcomes.
11. Evaluate and/or revise a solution to resolve or improve the impact of human activities on natural systems, and evaluate the outcomes

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS-3-5
Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts on Earth's systems.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze data using computational models in order to make valid and reliable scientific claims.</td><td>ESS3.D: Global Climate Change
• Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.</td><td>Stability and Change
• Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as sea level, glacial ice volumes, or atmosphere and ocean composition).

Content Limits
• Assessment is limited to one example of a climate change and its associated impacts.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Orientation, probabilistic, redistribute, volcanic ash, concentration, electromagnetic radiation, radiation, sea level, geochemical reaction, geoscience, greenhouse gas, atmospheric change, biosphere, global temperature, ice core, methane, glacier</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Anthropogenic, absorption spectrum, determinant, NOX, Carbon Footprint,</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS3-5:
• The model predictions for the Great Lakes region of the United States consist of increased precipitation of 5-30% during the spring and decreased precipitation of 5-10% in the summer.
• Concentrations of CO_2 under the higher emissions scenario for 2100 could reach as high as 850 parts per million (ppm).
• Global warming of 2°C is predicted by the year 2050
• The model mean global temperature change for a high emissions scenario is 4-6°</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations in global or regional climate models and their associated future impacts on Earth's systems.</td></tr>
<tr><td colspan="4">2. Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations in global or regional climate models to forecast regional climate change and the associated future impacts on Earth's systems. This may include sorting out distractors.</td></tr>
<tr><td colspan="4">3. Use relationships identified in the data to forecast the current rate of global or regional climate change and how it will affect Earth's systems.</td></tr>
<tr><td colspan="4">4. Identify patterns or evidence in the data that supports inferences about how the changing of global or regional climates will affect Earth's systems in the long term.</td></tr>
</table>

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS-3-6
Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.</td><td>ESS2.D: Weather and Climate
• Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. (secondary)

ESS3.D: Global Climate Change
• Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.</td><td>Systems and System Models
• When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere.
• An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.

Content Limits
• Assessment does not include running computational representations but is limited to using the published results of scientific computational models.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Orientation, probabilistic, redistribute, volcanic ash, concentration, electromagnetic radiation, radiation, sea level, geochemical reaction, geoscience, greenhouse gas, atmospheric change, biosphere, global temperature, ice core, methane, glacier</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Anthropogenic, absorption spectrum, determinant, NOX, Carbon Footprint,</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS3-6:
• Beetles are present throughout a forest. Chemicals are sprayed at intervals needed to control the beetles on one acre. Fifty years later, this acre is the only part of the forest that has oak trees.
• In July 2016, the size of the hypoxic area due to algae blooms in the Chesapeake Bay in late June was the second smallest since 1985.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

1. Use data to calculate or estimate the effect of human activity on Earth systems.
2. Illustrate, graph, or identify features or data that can be used to determine the relationships among Earth systems and how human activity is affecting those relationships.
3. Estimate or infer the effects of human activity on Earth systems.
4. Compile the data needed for an inference about the impacts of human activity on Earth systems. This can include sorting out the relevant data from the given information (or choosing relevant inputs for a simulation).
5. Using a simulator, test a prediction and evaluate the outcomes. This may include proposing modifications to the action to mitigate or the solution to the effect(s) of human activity on Earth systems.
6. Evaluate and/or critique models, simulations, or predictions in terms of identifiable limitations and whether or not they yield realistic results.

Appendix A. Change Log

Change	Section	Date